WinDriver™ PCI/ISA/CardBus User's Manual

Version 10.4.0

Jungo Ltd.

WinDriver™ PCI/ISA/CardBus User's Manual: Version 10.4.0

Copyright © Jungo Ltd. 2005–2011 All Rights Reserved.

Information in this document is subject to change without notice. The software described in this document is furnished under a license agreement. The software may be used, copied or distributed only in accordance with that agreement. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or any means, electronically or mechanically, including photocopying and recording for any purpose without the written permission of Jungo Ltd.

Brand and product names mentioned in this document are trademarks of their respective owners and are used here only for identification purposes.

Table of Contents

1. WinDriver Overview 1
    1.1. Introduction to WinDriver 1
    1.2. Background 2
        1.2.1. The Challenge 2
        1.2.2. The WinDriver Solution 2
    1.3. How Fast Can WinDriver Go? 3
    1.4. Conclusion 3
    1.5. WinDriver Benefits 4
    1.6. WinDriver Architecture 5
    1.7. What Platforms Does WinDriver Support? 6
    1.8. Limitations of the Different Evaluation Versions 6
    1.9. How Do I Develop My Driver with WinDriver? 7
        1.9.1. On Windows, Mac OS X, and Linux 7
        1.9.2. On Windows CE 7
    1.10. What Does the WinDriver Toolkit Include? 8
        1.10.1. WinDriver Modules 8
        1.10.2. Utilities 9
        1.10.3. WinDriver's Specific Chipset Support 10
        1.10.4. Samples 10
    1.11. Can I Distribute the Driver Created with WinDriver? 10
2. Understanding Device Drivers 11
    2.1. Device Driver Overview 11
    2.2. Classification of Drivers According to Functionality 11
        2.2.1. Monolithic Drivers 11
        2.2.2. Layered Drivers 12
        2.2.3. Miniport Drivers 13
    2.3. Classification of Drivers According to Operating Systems 14
        2.3.1. WDM Drivers 14
        2.3.2. VxD Drivers 15
        2.3.3. Unix Device Drivers 15
        2.3.4. Linux Device Drivers 15
        2.3.5. Mac OS X Device Drivers 16
    2.4. The Entry Point of the Driver 16
    2.5. Associating the Hardware with the Driver 16
    2.6. Communicating with Drivers 17
3. Installing WinDriver 18
    3.1. System Requirements 18
        3.1.1. Windows System Requirements 18
        3.1.2. Windows CE System Requirements 18
        3.1.3. Mac OS X System Requirements 19
        3.1.4. Linux System Requirements 19
    3.2. WinDriver Installation Process 20
        3.2.1. Windows WinDriver Installation Instructions 20
        3.2.2. Windows CE WinDriver Installation Instructions 21
            3.2.2.1. Installing WinDriver CE when Building New CE-Based Platforms..... 21

© Jungo Ltd. 2005–2011

3.2.2.2. Installing WinDriver CE when Developing Applications for Windows CE Computers 23
3.2.2.3. Windows CE Installation Note 24
3.2.3. Mac OS X WinDriver Installation Instructions 24
3.2.4. Linux WinDriver Installation Instructions 25
3.2.4.1. Preparing the System for Installation 25
3.2.4.2. Installation 26
3.2.4.3. Restricting Hardware Access on Linux 29
3.3. Upgrading Your Installation 29
3.4. Checking Your Installation 29
3.4.1. Windows, Mac OS X, and Linux Installation Check 29
3.4.2. Windows CE Installation Check 30
3.5. Uninstalling WinDriver 30
3.5.1. Windows WinDriver Uninstall Instructions 30
3.5.2. Mac OS X WinDriver Uninstall Instructions 32
3.5.3. Linux WinDriver Uninstall Instructions 33
4. Using DriverWizard 34
4.1. An Overview 34
4.2. DriverWizard Walkthrough 35
4.2.1. Automatic Code Generation 43
4.2.1.1. Generating the Code 43
4.2.1.2. The Generated PCI/PCMCIA/ISA C Code 43
4.2.1.3. The Generated Visual Basic and Delphi Code 44
4.2.1.4. The Generated C# Code 44
4.2.2. Compiling the Generated Code 45
4.2.2.1. Windows and Windows CE Compilation 45
4.2.2.2. Mac OS X Compilation 45
4.2.2.3. Linux Compilation 46
5. Developing a Driver 47
5.1. Using DriverWizard to Build a Device Driver 47
5.2. Writing the Device Driver Without DriverWizard 48
5.2.1. Include the Required WinDriver Files 48
5.2.2. Write Your Code 49
5.2.3. Configure and Build Your Code 50
5.3. Developing Your Driver on Windows CE Platforms 51
5.4. Developing in Visual Basic and Delphi 52
5.4.1. Using DriverWizard 52
5.4.2. Samples 52
5.4.3. Kernel PlugIn 52
5.4.4. Creating your Driver 52
6. Debugging Drivers 53
6.1. User-Mode Debugging 53
6.2. Debug Monitor 53
6.2.1. The **wddebug_gui** Utility 54
6.2.1.1. Running **wddebug_gui** for a Renamed Driver 56
6.2.2. The **wddebug** Utility 56
6.2.2.1. Console-Mode **wddebug** Execution 56
6.2.2.2. Windows CE GUI **wddebug** Execution 59

7. Enhanced Support for Specific Chipsets 61
7.1. Overview 61
7.2. Developing a Driver Using the Enhanced Chipset Support 61
8. PCI Express 63
8.1. PCI Express Overview 63
8.2. WinDriver for PCI Express 64
9. Advanced Issues 65
9.1. Performing Direct Memory Access (DMA) 65
9.1.1. Scatter/Gather DMA 66
9.1.1.1. Sample Scatter/Gather DMA Implementation 66
9.1.1.2. What Should You Implement? 68
9.1.2. Contiguous Buffer DMA 68
9.1.2.1. Sample Contiguous Buffer DMA Implementation 69
9.1.2.2. What Should You Implement? 70
9.1.3. Performing DMA on SPARC 70
9.2. Handling Interrupts 71
9.2.1. Interrupt Handling – Overview 71
9.2.2. WinDriver Interrupt Handling Sequence 72
9.2.3. Determining the Interrupt Types Supported by the Hardware 74
9.2.4. Determining the Interrupt Type Enabled for a PCI Card 75
9.2.5. Setting Up Kernel-Mode Interrupt Transfer Commands 75
9.2.5.1. Interrupt Mask Commands 76
9.2.5.2. Sample WinDriver Transfer Commands Code 76
9.2.6. WinDriver MSI/MSI-X Interrupt Handling 78
9.2.6.1. Windows MSI/MSI-X Device INF Files 78
9.2.7. Sample User-Mode WinDriver Interrupt Handling Code 79
9.2.8. Interrupts on Windows CE 80
9.2.8.1. Improving Interrupt Latency on Windows CE 81
9.3. Byte Ordering 82
9.3.1. Introduction to Endianness 82
9.3.2. WinDriver Byte Ordering Macros 83
9.3.3. Macros for PCI Target Access 83
9.3.4. Macros for PCI Master Access 84
10. Improving Performance 85
10.1. Overview 85
10.1.1. Performance Improvement Checklist 85
10.2. Improving the Performance of a User-Mode Driver 86
10.2.1. Using Direct Access to Memory-Mapped Regions 86
10.2.2. Block Transfers and Grouping Multiple Transfers 87
10.2.3. Performing 64-Bit Data Transfers 88
11. Understanding the Kernel PlugIn 89
11.1. Background 89
11.2. Do I Need to Write a Kernel PlugIn Driver? 89
11.3. What Kind of Performance Can I Expect? 90
11.4. Overview of the Development Process 90
11.5. The Kernel PlugIn Architecture 90
11.5.1. Architecture Overview 90
11.5.2. WinDriver's Kernel and Kernel PlugIn Interaction 91

© Jungo Ltd. 2005–2011

11.5.3. Kernel PlugIn Components 92
11.5.4. Kernel PlugIn Event Sequence 92
11.5.4.1. Opening a Handle from the User Mode to a Kernel PlugIn Driver 92
11.5.4.2. Handling User-Mode Requests from the Kernel PlugIn 93
11.5.4.3. Interrupt Handling – Enable/Disable and High Interrupt Request Level Processing 93
11.5.4.4. Interrupt Handling – Deferred Procedure Calls 94
11.5.4.5. Plug-and-Play and Power Management Events 95
11.6. How Does Kernel PlugIn Work? 95
11.6.1. Minimal Requirements for Creating a Kernel PlugIn Driver 95
11.6.2. Kernel PlugIn Implementation 96
11.6.2.1. Before You Begin 96
11.6.2.2. Write Your KP_Init Function 96
11.6.2.3. Write Your KP_Open Function(s) 98
11.6.2.4. Write the Remaining PlugIn Callbacks 103
11.6.3. Sample/Generated Kernel PlugIn Driver Code Overview 103
11.6.4. Kernel PlugIn Sample/Generated Code Directory Structure 104
11.6.4.1. pci_diag and kp_pci Sample Directories 104
11.6.4.2. The Generated DriverWizard Kernel PlugIn Directory 106
11.6.5. Handling Interrupts in the Kernel PlugIn 108
11.6.5.1. Interrupt Handling in the User Mode (Without Kernel PlugIn) 108
11.6.5.2. Interrupt Handling in the Kernel (Using a Kernel PlugIn) 109
11.6.6. Message Passing 111
12. Creating a Kernel PlugIn Driver 113
12.1. Determine Whether a Kernel PlugIn is Needed 113
12.2. Prepare the User-Mode Source Code 113
12.3. Create a New Kernel PlugIn Project 114
12.4. Open a Handle to the Kernel PlugIn 115
12.5. Set Interrupt Handling in the Kernel PlugIn 116
12.6. Set I/O Handling in the Kernel PlugIn 117
12.7. Compile Your Kernel PlugIn Driver 117
12.7.1. On Windows 117
12.7.2. On Mac OS X 120
12.7.3. On Linux 121
12.8. Install Your Kernel PlugIn Driver 122
12.8.1. On Windows 122
12.8.2. On Mac OS X 122
12.8.3. On Linux 123
13. Dynamically Loading Your Driver 124
13.1. Why Do You Need a Dynamically Loadable Driver? 124
13.2. Windows Dynamic Driver Loading 124
13.2.1. Windows Driver Types 124
13.2.2. The wdreg Utility 125
13.2.2.1. WDM Drivers 125
13.2.2.2. Non-WDM Drivers 126
13.2.3. Dynamically Loading/Unloading windrvr6.sys INF Files 128
13.2.4. Dynamically Loading/Unloading Your Kernel PlugIn Driver 129
13.3. Mac OS X Dynamic Driver Loading 129

13.3.1. Dynamically Loading Your Driver on Mac OS X 129
13.3.1.1. The wdreg Script 130
13.3.2. Dynamically Unloading Your Driver on Mac OS X 130
13.4. Linux Dynamic Driver Loading 131
13.5. Windows CE Dynamic Driver Loading 131
14. Distributing Your Driver 132
14.1. Getting a Valid License for WinDriver 132
14.2. Windows Driver Distribution 132
14.2.1. Preparing the Distribution Package 133
14.2.2. Installing Your Driver on the Target Computer 133
14.2.3. Installing Your Kernel PlugIn on the Target Computer 136
14.3. Windows CE Driver Distribution 137
14.3.1. Distribution to New Windows CE Platforms 137
14.3.2. Distribution to Windows CE Computers 139
14.4. Mac OS X Driver Distribution 140
14.4.1. Preparing the Distribution Package 140
14.4.2. Installing Your Driver on the Target Computer 140
14.5. Linux Driver Distribution 142
14.5.1. Kernel Modules 142
14.5.2. User-Mode Hardware Control Application/Shared Objects 143
14.5.3. Kernel PlugIn Modules 144
14.5.3.1. Rebuilding the Kernel PlugIn 146
14.5.4. Installation Script 146
15. Driver Installation – Advanced Issues 147
15.1. Windows INF Files 147
15.1.1. Why Should I Create an INF File? 147
15.1.2. How Do I Install an INF File When No Driver Exists? 148
15.1.3. How Do I Replace an Existing Driver Using the INF File? 148
15.2. Renaming the WinDriver Kernel Driver 149
15.2.1. Windows Driver Renaming 150
15.2.2. Mac OS X Driver Renaming 152
15.2.3. Linux Driver Renaming 153
15.3. Digital Driver Signing and Certification – Windows 7/Vista/Server 2008/ Server 2003/XP 154
15.3.1. Overview 154
15.3.1.1. Authenticode Driver Signature 155
15.3.1.2. WHQL Driver Certification 155
15.3.2. Driver Signing and Certification of WinDriver-Based Drivers 156
15.3.2.1. WHQL DTM Test Notes 157
15.4. Windows XP Embedded WinDriver Component 158
A. 64-Bit Operating Systems Support 160
A.1. Supported 64-Bit Architectures 160
A.2. Support for 32-Bit Applications on 64-Bit Windows and Linux Platforms 160
A.3. 32-Bit and 64-Bit Support on Mac OS X 161
A.3.1. Running 32-Bit Applications on 64-Bit Mac OS X Platforms 162
A.4. 64-Bit and 32-Bit Data Types 162
B. API Reference 163
B.1. WD_DriverName 163

B.2. WDC Library Overview 164
B.3. WDC High-Level API 165
B.3.1. Structures, Types and General Definitions 165
B.3.1.1. WDC_DEVICE_HANDLE 165
B.3.1.2. WDC_DRV_OPEN_OPTIONS Definitions 165
B.3.1.3. WDC_DIRECTION Enumeration 166
B.3.1.4. WDC_ADDR_MODE Enumeration 167
B.3.1.5. WDC_ADDR_RW_OPTIONS Enumeration 167
B.3.1.6. WDC_ADDR_SIZE Definitions 167
B.3.1.7. WDC_SLEEP_OPTIONS Definitions 168
B.3.1.8. WDC_DBG_OPTIONS Definitions 168
B.3.1.9. WDC_SLOT_U Union 170
B.3.1.10. WDC_PCI_SCAN_RESULT Structure 170
B.3.1.11. WDC_PCMCIA_SCAN_RESULT Structure 170
B.3.2. WDC_DriverOpen() 171
B.3.3. WDC_DriverClose() 172
B.3.4. WDC_PciScanDevices() 173
B.3.5. WDC_PciScanDevicesByTopology() 174
B.3.6. WDC_PciScanRegisteredDevices() 175
B.3.7. WDC_PcmciaScanDevices() 177
B.3.8. WDC_PciGetDeviceInfo() 178
B.3.9. WDC_PcmciaGetDeviceInfo() 179
B.3.10. WDC_PciDeviceOpen() 180
B.3.11. WDC_PcmciaDeviceOpen() 183
B.3.12. WDC_IsaDeviceOpen() 186
B.3.13. WDC_PciDeviceClose() 190
B.3.14. WDC_PcmciaDeviceClose() 191
B.3.15. WDC_IsaDeviceClose() 192
B.3.16. WDC_CardCleanupSetup() 193
B.3.17. WDC_KernelPlugInOpen() 194
B.3.18. WDC_CallKerPlug() 195
B.3.19. WDC_ReadMemXXX() 196
B.3.20. WDC_WriteMemXXX() 197
B.3.21. WDC_ReadAddrXXX() 198
B.3.22. WDC_WriteAddrXXX() 199
B.3.23. WDC_ReadAddrBlock() 200
B.3.24. WDC_WriteAddrBlock() 201
B.3.25. WDC_MultiTransfer() 202
B.3.26. WDC_AddrSpaceIsActive() 203
B.3.27. WDC_PciReadCfgBySlot() 204
B.3.28. WDC_PciWriteCfgBySlot() 205
B.3.29. WDC_PciReadCfg() 206
B.3.30. WDC_PciWriteCfg() 207
B.3.31. WDC_PciReadCfgBySlotXXX() 208
B.3.32. WDC_PciWriteCfgBySlotXXX() 209
B.3.33. WDC_PciReadCfgXXX() 211
B.3.34. WDC_PciWriteCfgXXX() 212
B.3.35. WDC_PcmciaReadAttribSpace() 213

© Jungo Ltd. 2005–2011

B.3.36. WDC_PcmciaWriteAttribSpace() 214
B.3.37. WDC_PcmciaSetWindow() 214
B.3.38. WDC_PcmciaSetVpp() 215
B.3.39. WDC_DMAContigBufLock() 216
B.3.40. WDC_DMASGBufLock() 218
B.3.41. WDC_DMABufUnlock() 220
B.3.42. WDC_DMASyncCpu() 221
B.3.43. WDC_DMASyncIo() 222
B.3.44. WDC_SharedBufferAlloc() 223
B.3.45. WDC_SharedBufferFree() 224
B.3.46. WDC_IntEnable() 225
B.3.47. WDC_IntDisable() 228
B.3.48. WDC_IntIsEnabled() 229
B.3.49. WDC_EventRegister() 229
B.3.50. WDC_EventUnregister() 232
B.3.51. WDC_EventIsRegistered() 233
B.3.52. WDC_SetDebugOptions() 233
B.3.53. WDC_Err() 234
B.3.54. WDC_Trace() 235
B.3.55. WDC_GetWDHandle() 236
B.3.56. WDC_GetDevContext() 236
B.3.57. WDC_GetBusType() 237
B.3.58. WDC_Sleep() 238
B.3.59. WDC_Version() 238
B.4. WDC Low Level API 239
B.4.1. WDC_ID_U Union 239
B.4.2. WDC_ADDR_DESC Structure 239
B.4.3. WDC_DEVICE Structure 240
B.4.4. PWDC_DEVICE 242
B.4.5. WDC_MEM_DIRECT_ADDR Macro 242
B.4.6. WDC_ADDR_IS_MEM Macro 243
B.4.7. WDC_GET_ADDR_DESC Macro 243
B.4.8. WDC_GET_ENABLED_INT_TYPE Macro 244
B.4.9. WDC_GET_INT_OPTIONS Macro 245
B.4.10. WDC_INT_IS_MSI Macro 246
B.4.11. WDC_GET_ENABLED_INT_LAST_MSG Macro 247
B.4.12. WDC_IS_KP Macro 247
B.5. WD_xxx Structures, Types and General Definitions 248
B.5.1. WD_BUS_TYPE Enumeration 248
B.5.2. ITEM_TYPE Enumeration 249
B.5.3. WD_PCMCIA_ACC_SPEED Enumeration 249
B.5.4. WD_PCMCIA_ACC_WIDTH Enumeration 249
B.5.5. WD_PCMCIA_VPP Enumeration 249
B.5.6. WD_PCI_ID Structure 250
B.5.7. WD_PCMCIA_ID Structure 250
B.5.8. WD_PCI_SLOT Structure 250
B.5.9. WD_PCMCIA_SLOT Structure 250
B.5.10. WD_ITEMS Structure 251

© Jungo Ltd. 2005–2011

B.5.11. WD_CARD Structure 256
B.5.12. WD_PCI_CARD_INFO Structure 256
B.5.13. WD_PCMCIA_CARD_INFO Structure 257
B.5.14. WD_DMA Structure 258
B.5.15. WD_TRANSFER Structure 261
B.6. Kernel PlugIn Kernel-Mode Functions 262
B.6.1. KP_Init 263
B.6.2. KP_Open 264
B.6.3. KP_Close 267
B.6.4. KP_Call 268
B.6.5. KP_Event 270
B.6.6. KP_IntEnable 271
B.6.7. KP_IntDisable 273
B.6.8. KP_IntAtIrql 274
B.6.9. KP_IntAtDpc 276
B.6.10. KP_IntAtIrqlMSI 277
B.6.11. KP_IntAtDpcMSI 279
B.6.12. COPY_TO_USER_OR_KERNEL, COPY_FROM_USER_OR_KERNEL 281
B.6.13. Kernel PlugIn Synchronization APIs 281
B.6.13.1. Kernel PlugIn Synchronization Types 282
B.6.13.2. kp_spinlock_init() 282
B.6.13.3. kp_spinlock_wait() 282
B.6.13.4. kp_spinlock_release() 283
B.6.13.5. kp_spinlock_uninit() 284
B.6.13.6. kp_interlocked_init() 284
B.6.13.7. kp_interlocked_uninit() 285
B.6.13.8. kp_interlocked_increment() 285
B.6.13.9. kp_interlocked_decrement() 286
B.6.13.10. kp_interlocked_add() 286
B.6.13.11. kp_interlocked_read() 287
B.6.13.12. kp_interlocked_set() 288
B.6.13.13. kp_interlocked_exchange() 288
B.7. Kernel PlugIn Structure Reference 289
B.7.1. WD_KERNEL_PLUGIN 289
B.7.2. WD_INTERRUPT 290
B.7.3. WD_KERNEL_PLUGIN_CALL 290
B.7.4. KP_INIT 291
B.7.5. KP_OPEN_CALL 292
B.8. User-Mode Utility Functions 294
B.8.1. Stat2Str 294
B.8.2. get_os_type 295
B.8.3. ThreadStart 295
B.8.4. ThreadWait 296
B.8.5. OsEventCreate 296
B.8.6. OsEventClose 297
B.8.7. OsEventWait 298
B.8.8. OsEventSignal 298

© Jungo Ltd. 2005–2011

B.8.9. OsEventReset 299
B.8.10. OsMutexCreate 299
B.8.11. OsMutexClose 300
B.8.12. OsMutexLock 301
B.8.13. OsMutexUnlock 301
B.8.14. PrintDbgMessage 302
B.8.15. WD_LogStart 303
B.8.16. WD_LogStop 304
B.8.17. WD_LogAdd 304
B.9. WinDriver Status Codes 305
B.9.1. Introduction 305
B.9.2. Status Codes Returned by WinDriver 305
C. Troubleshooting and Support 307
D. Evaluation Version Limitations 308
D.1. Windows WinDriver Evaluation Limitations 308
D.2. Windows CE WinDriver Evaluation Limitations 308
D.3. Mac OS X WinDriver Evaluation Limitations 309
D.4. Linux WinDriver Evaluation Limitations 310
E. Purchasing WinDriver 311
F. Distributing Your Driver – Legal Issues 312
G. Additional Documentation 313

List of Figures

1.1. WinDriver Architecture 5
2.1. Monolithic Drivers 12
2.2. Layered Drivers 13
2.3. Miniport Drivers 14
4.1. Create or Open a WinDriver Project 36
4.2. Select Your Plug-and-Play Device 36
4.3. DriverWizard INF File Information 38
4.4. PCI Resources 39
4.5. Define Registers 40
4.6. Read/Write Memory and I/O 40
4.7. Listen to Interrupts 41
4.8. Define Transfer Commands for Level-Sensitive Interrupts 41
4.9. Code Generation Options 42
4.10. Additional Driver Options 42
6.1. Start Debug Monitor 54
6.2. Debug Options 55
6.3. wddebug Windows CE Start Log Message 59
6.4. wddebug Windows CE Stop Log Message 60
11.1. Kernel PlugIn Architecture 91
11.2. Interrupt Handling Without Kernel PlugIn 109
11.3. Interrupt Handling With the Kernel PlugIn 110

© Jungo Ltd. 2005–2011

Chapter 1
WinDriver Overview

In this chapter you will explore the uses of WinDriver, and learn the basic steps of creating your driver.

This manual outlines WinDriver's support for PCI / PCMCIA / CardBus / ISA / EISA / CompactPCI / PCI Express devices.
WinDriver also supports the Universal Serial Bus (**USB**). For detailed information regarding WinDriver USB, please refer to the WinDriver product page on our web site (http://www.jungo.com/st/windriver.html) and to the **WinDriver USB Manual**, which is available online at http://www.jungo.com/st/support/support_windriver.html.

1.1. Introduction to WinDriver

WinDriver is a development toolkit that dramatically simplifies the difficult task of creating device drivers and hardware access applications. WinDriver includes a wizard and code generation features that automatically detect your hardware and generate the driver to access it from your application. The driver and application you develop using WinDriver is source code compatible across all supported operating systems [1.7]. The driver is binary compatible across Windows 7/Vista/Server 2008/Server 2003/XP, and across Mac OS X 10.5.x–10.6.x (using unified binaries).

Bus architecture support includes PCI/PCMCIA/CardBus/ISA/EISA/CompactPCI/PCI Express.
PCMCIA is supported only on Windows 7/Vista/Server 2008/Server 2003/XP.
CardBus, ISA, and EISA are supported on Windows 7/Vista/Server 2008/Server 2003/XP, Windows CE 4.x–7.x (including Windows Mobile), and Linux.

WinDriver provides a complete solution for creating high-performance drivers.

Don't let the size of this manual fool you. WinDriver makes developing device drivers an easy task that takes hours instead of months. Most of this manual deals with the features that WinDriver offers to the advanced user. However, most developers will find that reading this chapter and glancing through the DriverWizard and function reference chapters is all they need to successfully write their driver.

WinDriver supports development for all PCI / PCMCIA / CardBus / ISA / EISA / CompactPCI / PCI Express chipsets. Enhanced support is offered for PLX, Altera, AMCC and Xilinx PCI chipsets, as outlined in Chapter 7 of the manual.

Chapter 10 explains how to tune your driver code to achieve optimal performance, with special emphasis on WinDriver's Kernel PlugIn feature. This feature allows the developer to write and debug the entire device driver in the user mode, and later drop performance critical portions of the code into kernel mode. In this way the driver achieves optimal kernel-mode performance, while the developer need not sacrifice the ease of user-mode development. For a detailed overview of the Kernel PlugIn, refer to Chapters 11–12.

Visit Jungo's web site at http://www.jungo.com for the latest news about WinDriver and other driver development tools that Jungo offers.

1.2. Background

1.2.1. The Challenge

In protected operating systems such as Windows and Linux, a programmer cannot access hardware directly from the application level (user mode), where development work is usually done. Hardware can only be accessed from within the operating system itself (kernel mode or Ring-0), utilizing software modules called device drivers. In order to access a custom hardware device from the application level, a programmer must do the following:

- Learn the internals of the operating system he is working on.
- Learn how to write a device driver.
- Learn new tools for developing/debugging in kernel mode (WDK, ETK, DDI/DKI).
- Write the kernel-mode device driver that does the basic hardware input/output.
- Write the application in user mode that accesses the hardware through the device driver written in kernel mode.
- Repeat the first four steps for each new operating system on which the code should run.

1.2.2. The WinDriver Solution

- **Easy Development**: WinDriver enables Windows, Windows CE, Mac OS X, and Linux programmers to create PCI/PCMCIA/CardBus/ISA/EISA/CompactPCI/PCI Express based device drivers in an extremely short time. WinDriver allows you to create your driver in the familiar user-mode environment, using MS Visual Studio, Borland C++ Builder, Borland Delphi, Visual Basic 6.0, MS eMbedded Visual C++, MS Platform Builder C++, Xcode, GCC, or any other appropriate compiler/IDE. You do not need to have any device driver knowledge, nor do you have to be familiar with operating system internals, kernel programming, the WDK, ETK or DDI/DKI.

© Jungo Ltd. 2005–2011

- **Cross Platform**: The driver created with WinDriver will run on Windows 7 / Vista / Server 2008 / Server 2003 / XP, Windows CE (a.k.a. Windows Embedded Compact) 4.x–7.x (including Windows Mobile), Mac OS X 10.5.x–10.6.x, and Linux. In other words – write it once, run it on many platforms.

- **Friendly Wizards**: DriverWizard (included) is a graphical diagnostics tool that lets you view /define the device's resources and test the communication with the hardware with just a few mouse clicks, before writing a single line of code. Once the device is operating to your satisfaction, DriverWizard creates the skeletal driver source code, giving access functions to all the resources on the hardware.

- **Kernel-Mode Performance**: WinDriver's API is optimized for performance.
  For drivers that need kernel-mode performance, WinDriver offers the Kernel PlugIn. This powerful feature enables you to create and debug your code in user mode and run the performance-critical parts of your code (such as the interrupt handling or access to I/O mapped memory ranges) in kernel mode, thereby achieving kernel-mode performance (zero performance degradation). This unique feature allows the developer to run user-mode code in the OS kernel without having to learn how the kernel works. For a detailed overview of this feature, see Chapter 11.
  Kernel PlugIn is not implemented under Windows CE. In this operating system there is no separation between kernel mode and user mode, therefore top performance can be achieved without using the Kernel PlugIn. To improve the interrupt handling rate on Windows CE, follow the instructions in Section 9.2.8.1 of the manual.

1.3. How Fast Can WinDriver Go?

You can expect the same throughput using the WinDriver Kernel PlugIn as when using a custom kernel driver. Throughput is constrained only by the limitations of your operating system and hardware. A rough estimate of the throughput you can obtain using the Kernel PlugIn is approximately 100,000 interrupts per second.

1.4. Conclusion

Using WinDriver, a developer need only do the following to create an application that accesses the custom hardware:

- Start DriverWizard and detect the hardware and its resources.

- Automatically generate the device driver code from within DriverWizard, or use one of the WinDriver samples as the basis for the application (see Chapter 7 for an overview of WinDriver's enhanced support for specific chipsets).

- Modify the user-mode application, as needed, using the generated/sample functions to implement the desired functionality for your application.

© Jungo Ltd. 2005–2011

Your hardware access application will run on all the supported platforms [1.7] – just recompile the code for the target platform. The code is binary compatible across Windows 7/ Vista/Server 2008/Server 2003/XP platforms, and across Mac OS X 10.5.x–10.6.x platforms; there is no need to rebuild the code when porting it across binary-compatible platforms.

1.5. WinDriver Benefits

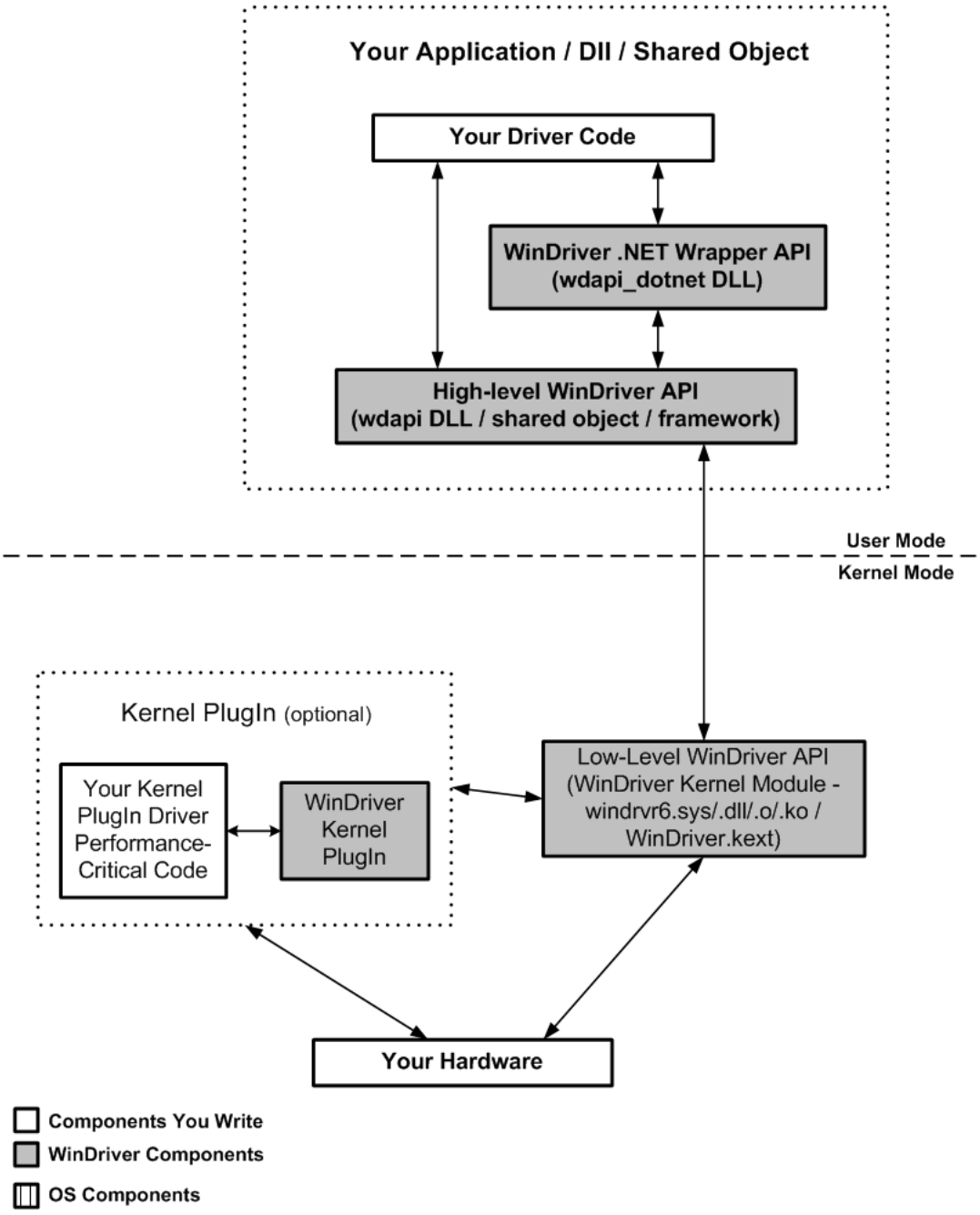
- Easy user-mode driver development.
- Kernel PlugIn for high-performance drivers.
- Friendly DriverWizard allows hardware diagnostics without writing a single line of code.
- Automatically generates the driver code for the project in C, C#, Delphi (Pascal), or Visual Basic 6.0.
- Supports any PCI/PCMCIA/CardBus/ISA/EISA/CompactPCI/PCI Express device, regardless of manufacturer.
- Enhanced support for PLX, Altera, AMCC and Xilinx chipsets frees the developer from the need to study the hardware's specification.
- Applications are binary compatible across Windows 7/Vista/Server 2008/Server 2003/XP, and across Mac OS X 10.5.x–10.6.x.
- Applications are source code compatible across all supported operating systems – Windows 7/ Vista/Server 2008/Server 2003/XP, Windows CE (a.k.a. Windows Embedded Compact) 4.x–7.x (including Windows Mobile), Mac OS X 10.5.x–10.6.x, and Linux.
- Can be used with common development environments, including MS Visual Studio, Borland C++ Builder, Borland Delphi, Visual Basic 6.0, MS eMbedded Visual C++, MS Platform Builder C++, Xcode, GCC, or any other appropriate compiler/IDE.
- No WDK, ETK, DDI or any system-level programming knowledge required.
- Supports I/O, DMA, interrupt handling and access to memory-mapped cards.
- Supports multiple CPUs and multiple PCI bus platforms (PCI / PCMCIA / CardBus / ISA / EISA / CompactPCI / PCI Express).
- Supports 64-bit PCI data transfers.
- Includes dynamic driver loader.
- Comprehensive documentation and help files.
- Detailed examples in C, C#, Delphi (Pascal), or Visual Basic 6.0.
- WHQL certifiable driver (Windows).

© Jungo Ltd. 2005–2011

- Two months of free technical support.
- No run-time fees or royalties.

1.6. WinDriver Architecture

Figure 1.1. WinDriver Architecture



For hardware access, your application calls one of the WinDriver user-mode functions. The user-mode function calls the WinDriver kernel, which accesses the hardware for you through the native calls of the operating system.

© Jungo Ltd. 2005–2011

WinDriver's design minimizes performance hits on your code, even though it is running in user mode. However, some hardware drivers have high performance requirements that cannot be achieved in user mode. This is where WinDriver's edge sharpens. After easily creating and debugging your code in user mode, you may drop the performance-critical modules of your code (such as a hardware interrupt handler) into the WinDriver Kernel PlugIn without changing them at all. Now, the WinDriver kernel calls this module from kernel mode, thereby achieving maximal performance. This allows you to program and debug in user mode, and still achieve kernel performance where needed. For a detailed overview of the Kernel PlugIn feature, see Chapter 11.
Kernel PlugIn is not implemented under Windows CE. In this operating system there is no separation between kernel mode and user mode, therefore top performance can be achieved without using the Kernel PlugIn. To improve the interrupt handling rate on Windows CE, follow the instructions in Section 9.2.8.1 of the manual.

1.7. What Platforms Does WinDriver Support?

WinDriver supports the following operating systems:

- Windows 7/Vista/Server 2008/Server 2003/XP – henceforth collectively: **Windows**
- Windows CE (a.k.a. Windows Embedded Compact) 4.x–7.x (including Windows Mobile) – henceforth collectively: **Windows CE**
- Mac OS X 10.5.x–10.6.x – henceforth collectively: **Mac OS X**
- Linux

The same source code will run on all supported platforms – simply recompile it for the target platform. The source code is binary compatible across Windows 7 / Vista / Server 2008 / Server 2003 / XP, and across Mac OS X 10.5.x–10.6.x; WinDriver executables can be ported among the binary-compatible platforms without recompilation.

Even if your code is meant only for one of the supported operating systems, using WinDriver will give you the flexibility to move your driver to another operating system in the future without needing to change your code.

1.8. Limitations of the Different Evaluation Versions

All the evaluation versions of WinDriver are full featured. No functions are limited or crippled in any way. The evaluation version of WinDriver varies from the registered version in the following ways:

- Each time WinDriver is activated, an *Unregistered* message appears.
- When using DriverWizard, a dialogue box with a message stating that an evaluation version is being run appears on every interaction with the hardware.

© Jungo Ltd. 2005–2011

- In the Linux and Windows CE versions, the driver will remain operational for 60 minutes, after which time it must be restarted.
- The Windows evaluation version expires 30 days from the date of installation.

For more details please refer to Appendix D.

1.9. How Do I Develop My Driver with WinDriver?

1.9.1. On Windows, Mac OS X, and Linux

1. Start DriverWizard and use it to diagnose your hardware – see details in Chapter 4.
2. Let DriverWizard generate skeletal code for your driver, or use one of the WinDriver samples as the basis for your driver application (see Chapter 7 for details regarding WinDriver's enhanced support for specific chipsets).
3. Modify the generated/sample code to suit your application's needs.
4. Run and debug your driver in the user mode.
5. If your code contains performance-critical sections, refer to Chapter 10 for suggestions on how to improve your driver's performance.

The code generated by DriverWizard is a diagnostics program that contains functions that read and write to any resource detected or defined (including custom-defined registers), enables your card's interrupts, listens to them, and more.

1.9.2. On Windows CE

1. Plug your hardware into a Windows host machine.
2. Diagnose your hardware using DriverWizard.
3. Let DriverWizard generate your driver's skeletal code.
4. Modify this code, using MS eMbedded Visual C++, to meet your specific needs. If you are using MS Platform Builder, activate it and insert the generated ***.pbp** into your workspace.
5. Test your driver on the target embedded Windows CE platorm.

© Jungo Ltd. 2005–2011

If you cannot plug your hardware into a Windows host machine, you can still use DriverWizard to generate code for your device by manually entering all your resources in the wizard. Let DriverWizard generate your code and then test it on your hardware using a serial connection. After verifying that the generated code works properly, modify it to meet your specific needs. You may also use (or combine) any of the sample files for your driver's skeletal code.

1.10. What Does the WinDriver Toolkit Include?

- A printed version of this manual
- Two months of free technical support (Phone/Fax/Email)
- WinDriver modules
- The WinDriver CD
  - Utilities
  - Chipset support APIs
  - Sample files

1.10.1. WinDriver Modules

- WinDriver (**WinDriver/include**) – the general purpose hardware access toolkit. The main files here are:
  - **windrvr.h**: Declarations and definitions of WinDriver's basic API.
  - **wdc_lib.h** and **wdc_defs.h**: Declarations and definitions of the WinDriver Card (WDC) library, which provides convenient wrapper APIs for accessing PCI/PCMCIA/CardBus/ISA/EISA/CompactPCI/PCI Express devices (see Section B.2).
  - **windrvr_int_thread.h**: Declarations of convenient wrapper functions to simplify interrupt handling.
  - **windrvr_events.h**: Declarations of APIs for handling and Plug-and-Play and power management events.
  - **utils.h**: Declarations of general utility functions.
  - **status_strings.h**: Declarations of API for converting WinDriver status codes to descriptive error strings.

© Jungo Ltd. 2005–2011

On Mac OS X, the WinDriver API is supplied in the form of a framework – **WDAPI.framework**. This framework is provided in the **WinDriver/redist** directory, and is copied, as part of the WinDriver installation, to the operating system's frameworks directory – **/Library/Frameworks**. Therefore, the include path on Mac OS X should be **/Library/Frameworks/WDAPI.framework/Headers**.

- DriverWizard (**WinDriver/wizard/wdwizard** or **/Applications/wdwizard.app** on Mac OS X) – a graphical application that diagnoses your hardware and enables you to easily generate code for your driver (refer to Chapter 4 for details).

- Debug Monitor – a debugging tool that collects information about your driver as it runs. This tool is available both as a fully graphical application – **WinDriver/util/wddebug_gui**, or **/Applications/wddebug_gui.app** on Mac OS X – and as a console-mode application – **WinDriver/util/wddebug**. The console-mode version also supports GUI execution on Windows CE platforms that don't have a command-line prompt.
  For details regarding the Debug Monitor, refer to Section 6.2.

- WinDriver distribution package (**WinDriver/redist**) – the files you include in the driver distribution to customers.

- WinDriver Kernel PlugIn – the files and samples needed to create a kernel-mode Kernel PlugIn driver (refer to Chapter 11 for details.)

- This manual – the full WinDriver manual (this document), in different formats, can be found under the **WinDriver/docs** directory.

1.10.2. Utilities

- **pci_dump.exe** (**WinDriver/util/pci_dump.exe**) – used to obtain a dump of the PCI configuration registers of the installed PCI cards.

- **pci_diag.exe** (**WinDriver/util/pci_diag.exe**) – used for reading/writing PCI configuration registers, accessing PCI I/O and memory ranges and handling PCI interrupts.

- **pci_scan.exe** (**WinDriver/util/pci_scan.exe**) – used to obtain a list of the PCI cards installed and the resources allocated for each card.

- **pcmcia_diag.exe** (**WinDriver/util/pcmcia_diag.exe**) – used for reading/writing PCMCIA attribute space, accessing PCMCIA I/O and memory ranges and handling PCMCIA interrupts.

- **pcmcia_scan.exe** (**WinDriver/util/pcmcia_scan.exe**) – used to obtain a list of the PCMCIA cards installed and the resources allocated for each card.

© Jungo Ltd. 2005–2011

1.10.3. WinDriver's Specific Chipset Support

WinDriver provides custom wrapper APIs and sample code for major PCI chipsets (see Chapter 7), including for the following chipsets:

- PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656 – **WinDriver/plx**
- AMCC S5933 – **WinDriver/amcc**
- Altera pci_dev_kit – **WinDriver/altera/pci_dev_kit**
- Xilinx Bus Master DMA (BMD) design and VirtexII – **WinDriver/xilinx**

1.10.4. Samples

In addition to the samples provided for specific chipsets [1.10.3], WinDriver includes a variety of samples that demonstrate how to use WinDriver's API to communicate with your device and perform various driver tasks.

- C samples: found under the **WinDriver/samples** directory.
  These samples also include the source code for the utilities listed above [1.10.2].
- .NET C# samples (Windows): found under the **WinDriver\csharp.net** directory.
- Delphi (Pascal) samples (Windows) **WinDriver\delphi\samples** directory.
- Visual Basic samples (Windows): found under the **WinDriver\vb\samples** directory.

1.11. Can I Distribute the Driver Created with WinDriver?

Yes. WinDriver is purchased as a development toolkit, and any device driver created using WinDriver may be distributed, royalties free, in as many copies as you wish. See the license agreement at (**WinDriver/docs/license.pdf**) for more details.

Chapter 2
Understanding Device Drivers

This chapter provides you with a general introduction to device drivers and takes you through the structural elements of a device driver.

Using WinDriver, you do not need to familiarize yourself with the internal workings of driver development. As explained in Chapter 1 of the manual, WinDriver enables you to communicate with your hardware and develop a driver for your device from the user mode, using only WinDriver's simple APIs, without any need for driver or kernel development knowledge.

2.1. Device Driver Overview

Device drivers are the software segments that provides an interface between the operating system and the specific hardware devices such as terminals, disks, tape drives, video cards and network media. The device driver brings the device into and out of service, sets hardware parameters in the device, transmits data from the kernel to the device, receives data from the device and passes it back to the kernel, and handles device errors.

A driver acts like a translator between the device and programs that use the device. Each device has its own set of specialized commands that only its driver knows. In contrast, most programs access devices by using generic commands. The driver, therefore, accepts generic commands from a program and then translates them into specialized commands for the device.

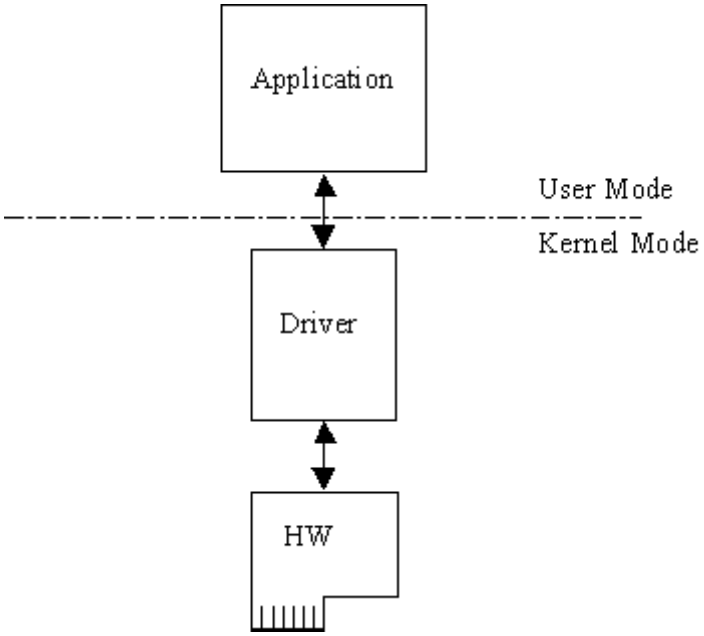
2.2. Classification of Drivers According to Functionality

There are numerous driver types, differing in their functionality. This subsection briefly describes three of the most common driver types.

2.2.1. Monolithic Drivers

Monolithic drivers are device drivers that embody all the functionality needed to support a hardware device. A monolithic driver is accessed by one or more user applications, and directly drives a hardware device. The driver communicates with the application through I/O control commands (IOCTLs) and drives the hardware using calls to the different WDK, ETK, DDI/DKI functions.

Figure 2.1. Monolithic Drivers



Monolithic drivers are supported in all operating systems including all Windows platforms and all Unix platforms.

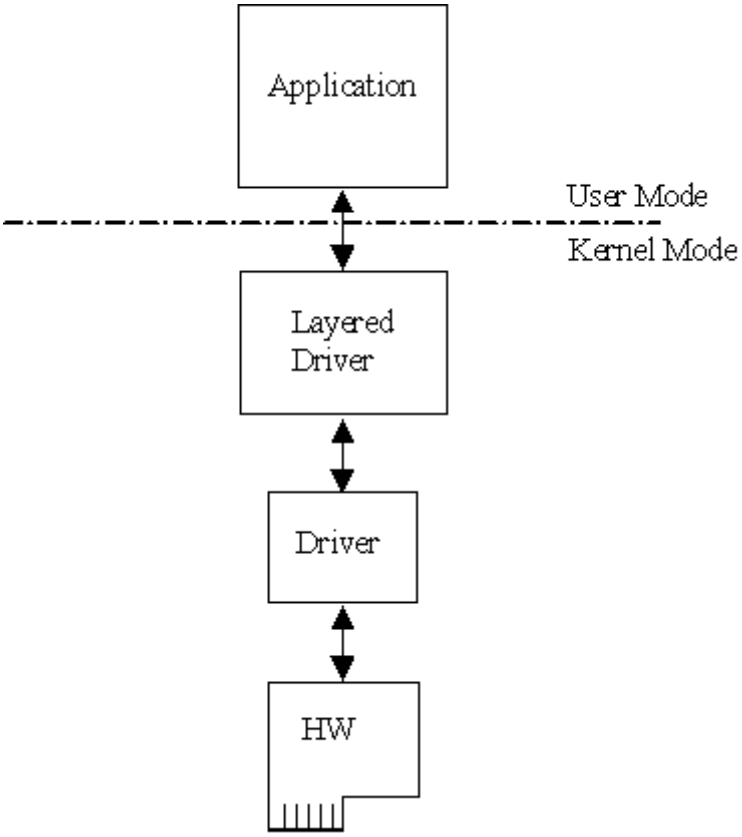
2.2.2. Layered Drivers

Layered drivers are device drivers that are part of a stack of device drivers that together process an I/O request. An example of a layered driver is a driver that intercepts calls to the disk and encrypts/decrypts all data being transferred to/from the disk. In this example, a driver would be hooked on to the top of the existing driver and would only do the encryption/decryption.

Layered drivers are sometimes also known as filter drivers, and are supported in all operating systems including all Windows platforms and all Unix platforms.

© Jungo Ltd. 2005–2011

Figure 2.2. Layered Drivers



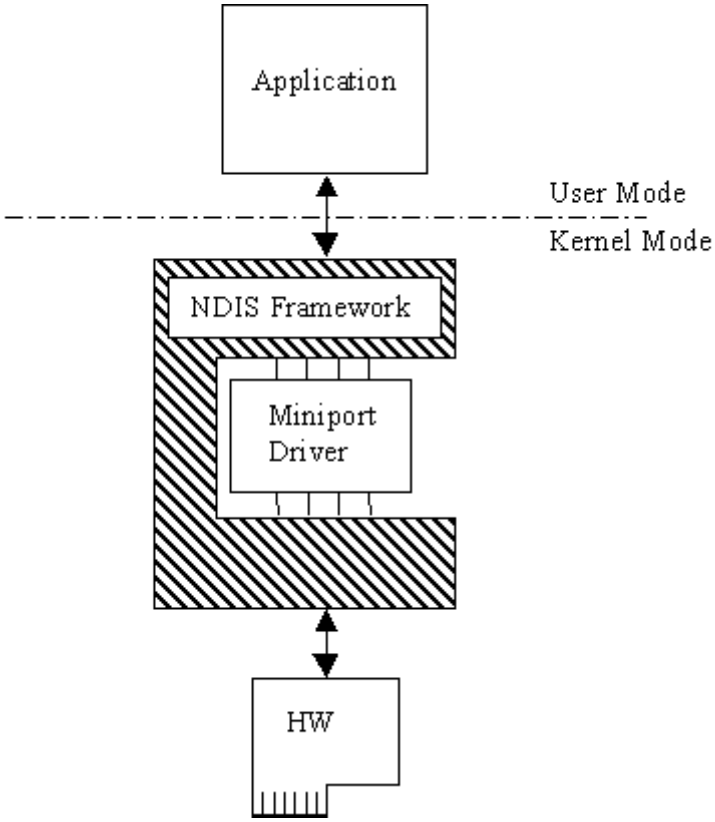
2.2.3. Miniport Drivers

A Miniport driver is an add-on to a class driver that supports miniport drivers. It is used so the miniport driver does not have to implement all of the functions required of a driver for that class. The class driver provides the basic class functionality for the miniport driver.
A class driver is a driver that supports a group of devices of common functionality, such as all HID devices or all network devices.

Miniport drivers are also called miniclass drivers or minidrivers, and are supported in the Windows NT (2000) family, namely Windows 7 / Vista / Server 2008 / Server 2003 / XP / 2000 / NT 4.0.

© Jungo Ltd. 2005–2011

Figure 2.3. Miniport Drivers



Windows 7/Vista/Server 2008/Server 2003/XP/2000/NT 4.0 provide several driver classes (called ports) that handle the common functionality of their class. It is then up to the user to add only the functionality that has to do with the inner workings of the specific hardware. The NDIS miniport driver is one example of such a driver. The NDIS miniport framework is used to create network drivers that hook up to NT's communication stacks, and are therefore accessible to common communication calls used by applications. The Windows NT kernel provides drivers for the various communication stacks and other code that is common to communication cards. Due to the NDIS framework, the network card developer does not have to write all of this code, only the code that is specific to the network card he is developing.

2.3. Classification of Drivers According to Operating Systems

2.3.1. WDM Drivers

Windows Driver Model (WDM) drivers are kernel-mode drivers within the Windows NT and Windows 98 operating system families. The Windows NT family includes Windows 7/Vista/ Server 2008/Server 2003/XP/2000/NT 4.0, and the Windows 98 family includes Windows 98 and Windows Me.

© Jungo Ltd. 2005–2011

WDM works by channeling some of the work of the device driver into portions of the code that are integrated into the operating system. These portions of code handle all of the low-level buffer management, including DMA and Plug-and-Play (Pnp) device enumeration.

WDM drivers are PnP drivers that support power management protocols, and include monolithic drivers, layered drivers and miniport drivers.

2.3.2. VxD Drivers

VxD drivers are Windows 95/98/Me Virtual Device Drivers, often called VxDs because the file names end with the .vxd extension. VxD drivers are typically monolithic in nature. They provide direct access to hardware and privileged operating system functions. VxD drivers can be stacked or layered in any fashion, but the driver structure itself does not impose any layering.

2.3.3. Unix Device Drivers

In the classic Unix driver model, devices belong to one of three categories: character (char) devices, block devices and network devices. Drivers that implement these devices are correspondingly known as char drivers, block drivers or network drivers. Under Unix, drivers are code units linked into the kernel that run in privileged kernel mode. Generally, driver code runs on behalf of a user-mode application. Access to Unix drivers from user-mode applications is provided via the file system. In other words, devices appear to the applications as special device files that can be opened.

Unix device drivers are either layered or monolithic drivers. A monolithic driver can be perceived as a one-layer layered driver.

2.3.4. Linux Device Drivers

Linux device drivers are based on the classic Unix device driver model [2.3.3]. In addition, Linux introduces some new characteristics.

Under Linux, a block device can be accessed like a character device, as in Unix, but also has a block-oriented interface that is invisible to the user or application.

Traditionally, under Unix, device drivers are linked with the kernel, and the system is brought down and restarted after installing a new driver. Linux introduces the concept of a dynamically loadable driver called a module. Linux modules can be loaded or removed dynamically without requiring the system to be shut down. A Linux driver can be written so that it is statically linked or written in a modular form that allows it to be dynamically loaded. This makes Linux memory usage very efficient because modules can be written to probe for their own hardware and unload themselves if they cannot find the hardware they are looking for.

Like Unix device drivers, Linux device drivers are either layered or monolithic drivers.

© Jungo Ltd. 2005–2011

2.3.5. Mac OS X Device Drivers

Mac OS X provides most of the Unix device I/O mechanisms, using character or block devices. These mechanisms are traditionally used on Mac OS X to access specific types of devices, such as disk devices, serial-port devices, and pseudo devices (with no actual hardware backing). However, Mac OS X also supports a different mechanism for accessing hardware devices, using I/O Kit user clients – which are basically remote procedure-call or system-call interfaces that enable calling kernel driver functions from an application. The I/O Kit also provides a standardized mechanism for retrieving information about connected hardware devices. Most hardware device drivers on Mac OS X are implemented using the I/O Kit mechanism.

Mac OS X device drivers are either layered or monolithic drivers, and like Linux and WDM Windows drivers, they may be dynamically loaded and unloaded.

2.4. The Entry Point of the Driver

Every device driver must have one main entry point, like the `main`() function in a C console application. This entry point is called `DriverEntry`() in Windows and `init_module`() in Linux. When the operating system loads the device driver, this driver entry procedure is called.

There is some global initialization that every driver needs to perform only once when it is loaded for the first time. This global initialization is the responsibility of the `DriverEntry`()/`init_module`() routine. The entry function also registers which driver callbacks will be called by the operating system. These driver callbacks are operating system requests for services from the driver. In Windows, these callbacks are called *dispatch routines*, and in Linux they are called *file operations*. Each registered callback is called by the operating system as a result of some criteria, such as disconnection of hardware, for example.

2.5. Associating the Hardware with the Driver

Operating systems differ in the ways they associate a device with a specific driver.

In Windows, the hardware–driver association is performed via an INF file, which registers the device to work with the driver. This association is performed before the `DriverEntry`() routine is called. The operating system recognizes the device, checks its database to identify which INF file is associated with the device, and according to the INF file, calls the driver's entry point.

In Mac OS X, the hardware–driver association is performed via an **Info.plist** file, which resides in the driver's kernel extension folder (***.kext**) and contains the required information regarding which hardware to associate with the driver.
As in Windows, this association is performed before the `DriverEntry`() routine is called. The operating system recognizes the device, identifies the **Info.plist** file associated with this device, and proceeds to call the relevant driver entry point.

In Linux, the hardware–driver association is defined in the driver's `init_module`() routine. This routine includes a callback that indicates which hardware the driver is designated to handle. The operating system calls the driver's entry point, based on the definition in the code.

© Jungo Ltd. 2005–2011

2.6. Communicating with Drivers

Communication between a user-mode application and the driver that drives the hardware, is implemented differently for each operating system, using the custom OS Application Programming Interfaces (APIs).

On Windows, Windows CE, and Linux, the application can use the OS file-access API to open a handle to the driver (e.g., using the Windows `CreateFile`() function or using the Linux `open`() function), and then read and write from/to the device by passing the handle to the relevant OS file-access functions (e.g., the Windows `ReadFile`() and `WriteFile`() functions, or the Linux `read`() and `write`() functions). On Mac OS X, it's not possible to use file-access APIs to directly access the hardware from a user-mode application.

On Windows, Windows CE, Mac OS X, and Linux, the application sends requests to the driver via I/O control (IOCTL) calls, using the custom OS APIs provided for this purpose (e.g., the Windows `DeviceIoControl`() function, the Mac OS X `IoConnectCallMethod`() method, or the Linux `ioctl`() function). On Mac OS X, the driver also sends requests to the application via IOCTL calls.
The data passed between the driver and the application via the IOCTL calls is encapsulated using custom OS mechanisms. For example, on Windows the data is passed via an I/O Request Packet (IRP) structure, and is encapsulated by the I/O Manager.

© Jungo Ltd. 2005–2011

Chapter 3
Installing WinDriver

This chapter takes you through the process of installing WinDriver on your development platform, and shows you how to verify that your WinDriver is properly installed. The last section discusses the uninstall procedure. To find out how to install the driver you create on target platforms, refer to Chapter 14.

3.1. System Requirements

3.1.1. Windows System Requirements

- Any x86 32-bit or 64-bit (x64: AMD64 or Intel EM64T) processor
- Any development environment supporting C, .NET, VB or Delphi
- Windows XP requires at least SP2

3.1.2. Windows CE System Requirements

- An x86, MIPS, or ARM target platform running Windows CE (a.k.a. Windows Embedded Compact) 4.x–7.x (including Windows Mobile)
- Windows 7/Vista/Server 2008/Server 2003/XP host development platform
- IDE:
  - For **Windows CE 4.x–5.x** (including Windows Mobile):
    - Microsoft eMbedded Visual C++ or Microsoft Visual Studio 2005/2008, with a corresponding target SDK

    OR
    - Microsoft Platform Builder with a corresponding Board Support Package (BSP) for the target platform
  - For **Windows CE 6.x**: Microsoft Visual Studio 2005/2008 with a corresponding target SDK or with the Windows CE 6.0 plugin
  - For **Windows CE 7.x**: Microsoft Visual Studio 2008 with the Windows CE 7 plugin

3.1.3. Mac OS X System Requirements

- CPU and OS:
  - Any x86 or x86_64 platform running 32-bit Mac OS X 10.5.x or newer
  - Any x86_64 platform running 64-bit Mac OS X 10.6.x or newer
  - Any PowerPC (PPC) platform running Mac OS X 10.5.x
- Xcode:
  - For Mac OS X version 10.6 – Xcode version 3.2
  - For Mac OS X version 10.5 – Xcode version 3.1 or 3.2

Jungo strives to support new Mac OS X and Xcode versions as close as possible to their release. To find out the latest supported versions, refer to the WinDriver release notes (found online at http://www.jungo.com/st/wdver.html).

3.1.4. Linux System Requirements

- Any 32-bit x86 processor with a Linux 2.2.x, 2.4.x or 2.6.x kernel
  or:
  Any 64-bit x86 AMD64 or Intel EM64T (**x86_64**) processor with a Linux 2.4.x or 2.6.x kernel
  or:
  Any PowerPC 32-bit processor with a Linux 2.4.x or 2.6.x kernel
  or:
  Any PowerPC 64-bit processor with a Linux 2.6.x kernel

Jungo strives to support new Linux kernel versions as close as possible to their release. To find out the latest supported kernel version, refer to the WinDriver release notes (found online at http://www.jungo.com/st/wdver.html).

- A GCC compiler

The version of the GCC compiler should match the compiler version used for building the running Linux kernel.

- Any 32-bit or 64-bit development environment (depending on your target configuration) supporting C for user mode
- On your development PC: **glibc2.3.x**
- **libstdc++.so.5** – required for running GUI WinDriver applications (e.g., DriverWizard [4]; Debug Monitor [6.2])

© Jungo Ltd. 2005–2011

3.2. WinDriver Installation Process

The WinDriver CD contains all versions of WinDriver for the supported operating systems. The CD's root directory contains the Windows 7 / Vista / Server 2008 / Server 2003 / XP version. The installation of this version will begin automatically when you insert the CD into the CD drive on your Windows development machine. The other versions of WinDriver are located in **<OS>** subdirectories (for example: **Linux**; **Wince**).

3.2.1. Windows WinDriver Installation Instructions

Driver installation on Windows requires administrator privileges.

1. Insert the WinDriver CD into your CD-ROM drive, or double-click the downloaded installation file – **WD1040.EXE** – and follow the installation instructions.

   When using the installation CD, wait a few seconds for the installation to begin automatically. If this does not happen, double-click the file **WD1040.EXE** in the CD, and click the **Install WinDriver** button.

2. At the end of the installation, you may be prompted to reboot your computer.

- The WinDriver installation defines a **`WD_BASEDIR`** environment variable, which is set to point to the location of your WinDriver directory, as selected during the installation. This variable is used during the DriverWizard [4] code generation – it determines the default directory for saving your generated code and is used in the include paths of the generated project/make files. This variable is also used in the sample Kernel PlugIn projects and makefiles.

- If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

© Jungo Ltd. 2005–2011

The following steps are for registered users only:

To register your copy of WinDriver with the license you received from Jungo, follow these steps:

3. Start DriverWizard: **Start | Programs | WinDriver | DriverWizard**.

4. Select the **Register WinDriver** option from the **File** menu, and insert the license string you received from Jungo.

5. Click the **Activate License** button.

6. To register source code that you developed during the evaluation period, refer to the documentation of `WDC_DriverOpen()` [B.3.2]. When using the low-level `WD_xxx` API instead of the `WDC_xxx` API [B.2] (which is used by default), refer to the documentation of `WD_License()` in the **WinDriver PCI Low-Level API Reference**.

3.2.2. Windows CE WinDriver Installation Instructions

3.2.2.1. Installing WinDriver CE when Building New CE-Based Platforms

- The following instructions apply to platform developers who build Windows CE kernel images using Windows CE Platform Builder or using MS Visual Studio 2005/2008 with the appropriate Windows CE plugin. The instructions use the notation **'Windows CE IDE'** to refer to either of these platforms.

- We recommend that you read Microsoft's documentation and understand the Windows CE and device driver integration procedure before you perform the installation.

1. Modify the project registry file to add an entry for your target device:

   - *If you select to use the WinDriver component* (refer to Step 2), modify **WinDriver\samples\wince_install\<TARGET_CPU>\WinDriver.reg** (e.g., **WinDriver\samples\wince_install\ARMV4I\WinDriver.reg**).

   - *Otherwise*, modify **WinDriver\samples\wince_install\project_wd.reg**.

2. *For **Windows CE 4.x–5.x** only*, you can simplify the driver integration into your Windows CE platform by following the procedure described in this step, before the Sysgen platform compilation stage.

   Note:

   - Developers who use Windows CE 6.x and higher should skip to the next step (Step 3).

- This procedure provides a convenient method for integrating WinDriver into your Windows CE platform. If you select not to use this method, you will need to perform the manual integration steps described in Step 4 below, after the Sysgen stage.

- The procedure described in this step also adds the WinDriver kernel module (**windrvr6.dll**) to your OS image. This is a necessary step if you want the WinDriver CE kernel file (**windrvr6.dll**) to be a permanent part of the Windows CE image (**NK.BIN**), which is the case if you select to transfer the file to your target platform using a boot disk. However, if you prefer to have the file **windrvr6.dll** loaded on demand via the CESH/ PPSH services, you need to perform the manual integration method described in Step 4 instead of performing the procedure described in the present step.

  a. Run the Windows CE IDE and open your platform.

  b. From the **File** menu select **Manage Catalog Items....**, click the **Import...** button, and select the **WinDriver.cec** file from the relevant **WinDriver\samples\wince_install\<TARGET_CPU>** directory (e.g., **WinDriver\samples\wince_install\ARMV4I**). This will add a WinDriver component to the Platform Builder Catalog.

  c. In the **Catalog** view, right-click the mouse on the **WinDriver Component** node in the **Third Party** tree, and select **Add to OS design**.

3. Compile your Windows CE platform (Sysgen stage).

4. If you did not perform the procedure described in Step 2 above, perform the following steps after the Sysgen stage in order to manually integrate the driver into your platform.
   Note: If you followed the procedure described in Step 2, skip this step and go directly to Step 5.

   a. Run the Windows CE IDE and open your platform.

   b. Select **Open Release Directory** from the **Build** menu.

   c. Copy the WinDriver CE kernel file – **WinDriver\redist\<TARGET_CPU>\windrvr6.dll** – to the **%_FLATRELEASEDIR%** subdirectory on the target development platform (should be the current directory in the new command window).

   d. Append the contents of **WinDriver\samples\wince_install\project_wd.reg** to the **%_FLATRELEASEDIR%\project.reg** registry file.

   e. Copy the contents of the **WinDriver\samples\wince_install\project_wd.bib** file to the FILES section of the binary image builder file – **%_FLATRELEASEDIR%\project.bib**. Then uncomment the line that matches the target platform (see the "TODO" comments in the copied text).

© Jungo Ltd. 2005–2011

This step is only necessary if you want the WinDriver CE kernel file (**windrvr6.dll**) to be a permanent part of the Windows CE image (**NK.BIN**), which is the case if you select to transfer the file to your target platform using a boot disk. If you prefer to have the file **windrvr6.dll** loaded on demand via the CESH/PPSH services, you do not need to perform this step until you build a permanent kernel.

5. Select **Make Run-Time Image** from the **Build** menu, and name the new image **NK.BIN**.

6. Download your new kernel to the target platform and initialize it either by selecting **Attach Device** from the **Target** menu, or by using a boot disk. For Windows CE 4.x, the menu is called **Download/Initialize** rather than **Attach Device**.

7. Restart your target CE platform. The WinDriver CE kernel will automatically load.

8. Compile and run the sample programs to make sure that WinDriver CE is loaded and is functioning correctly (see Section 3.4.2, which describes how to check your installation).

3.2.2.2. Installing WinDriver CE when Developing Applications for Windows CE Computers

Unless otherwise specified, 'Windows CE' references in this section include all supported Windows CE platforms, including Windows Mobile.

The following instructions apply to driver developers who do not build the Windows CE kernel, but only download their drivers, built using MS eMbedded Visual C++ or MS Visual Studio 2005/2008 to a ready-made Windows CE platform.

1. Insert the WinDriver CD into your Windows host CD drive.

2. Exit the automatic installation.

3. Copy WinDriver's kernel module – **windrvr6.dll** – from the **WinDriver\redist\WINCE\<TARGET_CPU>** directory on the Windows host development PC to the **Windows** directory on your target Windows CE platform.

© Jungo Ltd. 2005–2011

4. Add WinDriver to the list of device drivers Windows CE loads on boot:

   - Modify the registry according to the entries documented in the file **WinDriver\samples\wince_install\project_wd.reg**. This can be done using the Windows CE Pocket Registry Editor on the hand-held CE computer, or by using the Remote CE Registry Editor Tool supplied with MS eMbedded Visual C++ or MS Visual Studio 2005/2008. Note that in order to use the Remote CE Registry Editor tool you will need to have Windows CE Services installed on your Windows host platform.

   - On many versions of Windows CE, the operating system's security scheme prevents the loading of unsigned drivers at boot time, therefore the WinDriver kernel module has to be reloaded after boot. To load WinDriver on the target Windows CE platform every time the OS is started, copy the **WinDriver\redist\Windows_Mobile_5_ARMV4I\wdreg.exe** utility to the **Windows\StartUp** directory on the target PC.

5. Restart your target CE computer. The WinDriver CE kernel will automatically load. You will have to do a warm reset rather than just suspend/resume (use the reset or power button on your target CE computer).

6. Compile and run the sample programs to make sure that WinDriver CE is loaded and is functioning correctly (see Section 3.4, which describes how to check your installation).

3.2.2.3. Windows CE Installation Note

The WinDriver installation on the host Windows 7 / Vista / Server 2008 / Server 2003 / XP PC defines a **WD_BASEDIR** environment variable, which is set to point to the location of your WinDriver directory, as selected during the installation. This variable is used during the DriverWizard [4] code generation – it determines the default directory for saving your generated code, and is used in the include paths of the generated project/make files.

Note that if you install the WinDriver Windows 7 / Vista / Server 2008 / Server 2003 / XP toolkit on the same host PC, the installation will override the value of the `WD_BASEDIR` variable from the Windows CE installation.

3.2.3. Mac OS X WinDriver Installation Instructions

Driver installation on Mac OS X requires root privileges.

1. Insert the WinDriver CD into the CD drive on your Mac OS X development machine, or copy the downloaded installation package to your preferred location.

2. Double-click the installation package for your development platform – **WD1040MAC.pkg** for 32-bit platforms, and **WD1040MACX64.pkg** for 64-bit platforms.

The following is done automatically as part of the installation:

- The WinDriver kernel module – **WinDriver.kext** – is installed to **/System/Library/Extensions**.
- The WinDriver API framework – **WDAPI.framework** – is installed to **/Library/Frameworks**.
- Graphical WinDriver applications, such as the DriverWizard (**wdwizard.app**) and the Debug Monitor (**wddebug_gui.app**), are copied to the OS's **/Applications** folder.

The following steps are for registered users only:

To register your copy of WinDriver with the license you received from Jungo, follow these steps:

3. Start DriverWizard, either by double-clicking **/Applications/wdwizard.app**, or by running the following command from a command-line prompt:
   `$ /Applications/wdwizard.app/Contents/MacOS/wdwizard`
4. Select the **Register WinDriver** option from the **File** menu, and insert the license string you received from Jungo.
5. Click the **Activate License** button.
6. To register source code that you developed during the evaluation period, refer to the documentation of `WDC_DriverOpen()` [B.3.2]. When using the low-level `WD_xxx` API instead of the `WDC_xxx` API [B.2] (which is used by default), refer to the documentation of `WD_License()` in the **WinDriver PCI Low-Level API Reference**.

3.2.4. Linux WinDriver Installation Instructions

3.2.4.1. Preparing the System for Installation

In Linux, kernel modules must be compiled with the same header files that the kernel itself was compiled with. Since WinDriver installs kernel modules, it must compile with the header files of the Linux kernel during the installation process.

Therefore, before you install WinDriver for Linux, verify that the Linux source code and the file **versions.h** are installed on your machine:

Install the Linux kernel source code:

- If you have yet to install Linux, install it, including the kernel source code, by following the instructions for your Linux distribution.
- If Linux is already installed on your machine, check whether the Linux source code was installed. You can do this by looking for 'linux' in the **/usr/src** directory. If the source code is not installed, either install it, or reinstall Linux with the source code, by following the instructions for your Linux distribution.

© Jungo Ltd. 2005–2011

Install version.h:

- The file **version.h** is created when you first compile the Linux kernel source code. Some distributions provide a compiled kernel without the file **version.h**. Look under **/usr/src/linux/include/linux** to see if you have this file. If you do not, please follow these steps:

  1. Become super user:
     ```
     $ su
     ```
  2. Change directory to the Linux source directory:
     ```
     # cd /usr/src/linux
     ```
  3. Type:
     ```
     # make xconfig
     ```
  4. Save the configuration by choosing **Save and Exit**.
  5. Type:
     ```
     # make dep
     ```
  6. Exit super user mode:
     ```
     # exit
     ```

To run GUI WinDriver applications (e.g., DriverWizard [4]; Debug Monitor [6.2]) you must also have version 5.0 of the **libstdc++** library – **libstdc++.so.5**. If you do not have this file, install it from the relevant RPM in your Linux distribution (e.g., **compat-libstdc++**).

Before proceeding with the installation, you must also make sure that you have a *linux* symbolic link. If you do not, create one by typing
```
/usr/src$ ln -s <target kernel>/linux
```
For example, for the Linux 2.4 kernel type
```
/usr/src$ ln -s linux-2.4/ linux
```

3.2.4.2. Installation

1. Insert the WinDriver CD into your Linux machine's CD drive or copy the downloaded file to your preferred directory.
2. Change directory to your preferred installation directory, for example to your home directory:
   ```
   $ cd ~
   ```

   The path to the installation directory must not contain any spaces.
3. Extract the WinDriver distribution file – **WD1040LN.tgz**:
   ```
   $ tar xvzf /<file location>/WD1040LN.tgz
   ```

For example:

- From a CD:
  $ tar xvzf /mnt/cdrom/LINUX/WD1040LN.tgz

- From a downloaded file:
  $ tar xvzf /home/username/WD1040LN.tgz

4. Change directory to your WinDriver **redist** directory (the tar automatically creates a **WinDriver** directory):
   $ cd <WinDriver directory path>/redist

5. Install WinDriver:

   a. **<WinDriver directory>/redist$**

      ./configure --disable-usb-support

      The **configure** script creates a **makefile** based on your specific running kernel. You may run the **configure** script based on another kernel source you have installed, by adding the flag `--with-kernel-source=<path>` to the configure script. The <path> is the full path to the kernel source directory, e.g., **/usr/src/linux**.
      If the Linux kernel version is 2.6.26 or higher, **configure** generates makefiles that use **kbuild** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by passing the **--enable-kbuild** flag to **configure**.

   b. **<WinDriver directory>/redist$ make**

   c. Become super user:
      <WinDriver directory>/redist$ su

   d. Install the driver:
      <WinDriver directory>/redist# make install

6. Create a symbolic link so that you can easily launch the DriverWizard GUI:
   $ ln -s <path to WinDriver>/wizard/wdwizard /usr/bin/wdwizard

7. Change the read and execute permissions on the file **wdwizard** so that ordinary users can access this program.

© Jungo Ltd. 2005–2011

8. Change the user and group IDs and give read/write permissions to the device file **/dev/windrvr6** depending on how you wish to allow users to access hardware through the device. If you are using a Linux 2.6.x kernel that has the **udev** file system, change the permissions by modifying your **/etc/udev/permissions.d/50-udev.permissions** file. For example, add the following line to provide read and write permissions:
   `windrvr6:root:root:0666`
   Otherwise, use the **`chmod`** command, for example:
   `chmod 666 /dev/windrvr6`

9. Define a new **`WD_BASEDIR`** environment variable and set it to point to the location of your WinDriver directory, as selected during the installation. This variable is used in the make and source files of the WinDriver samples and generated DriverWizard [4] code, and is also used to determine the default directory for saving your generated DriverWizard projects. If you do not define this variable you will be instructed to do so when attempting to build the sample/generated code using the WinDriver makefiles.

10. Exit super user mode:
    `# exit`

11. You can now start using WinDriver to access your hardware and generate your driver code!

Use the **WinDriver/util/wdreg** script to load the WinDriver kernel module [13.4].

The following steps are for registered users only:

To register your copy of WinDriver with the license you received from Jungo, follow these steps:

11. Start DriverWizard:
    `$ <path to WinDriver>/wizard/wdwizard`

12. Select the **Register WinDriver** option from the **File** menu, and insert the license string you received from Jungo.

13. Click the **Activate License** button.

14. To register source code that you developed during the evaluation period, refer to the documentation of `WDC_DriverOpen()` [B.3.2]. When using the low-level `WD_xxx` API instead of the `WDC_xxx` API [B.2] (which is used by default), refer to the documentation of `WD_License()` in the **WinDriver PCI Low-Level API Reference**.

© Jungo Ltd. 2005–2011

3.2.4.3. Restricting Hardware Access on Linux

Since **/dev/windrvr6** gives direct hardware access to user programs, it may compromise kernel stability on multi-user Linux systems. Please restrict access to DriverWizard and the device file **/dev/windrvr6** to trusted users.

For security reasons the WinDriver installation script does not automatically perform the steps of changing the permissions on **/dev/windrvr6** and the DriverWizard application (**wdwizard**).

3.3. Upgrading Your Installation

To upgrade to a new version of WinDriver on Windows, follow the steps outlined in Section 3.2.1, which illustrate the process of installing WinDriver for Windows 7 / Vista / Server 2008 / Server 2003 / XP. You can either choose to overwrite the existing installation or install to a separate directory.

After installation, start DriverWizard and enter the new license string, if you have received one. This completes the upgrade of WinDriver.

To upgrade your source code, pass the new license string as a parameter to `WDC_DriverOpen()` [B.3.2] (or to `WD_License()` – see the **WinDriver PCI Low-Level API Reference** – when using the low-level `WD_xxx` API instead of the `WDC_xxx` API [B.2].

The procedure for upgrading your installation on other operating systems is the same as the one described above. Please check the respective installation sections for installation details.

3.4. Checking Your Installation

3.4.1. Windows, Mac OS X, and Linux Installation Check

1. Start DriverWizard – **<path to WinDriver>/wizard/wdwizard** or **/Applications/wdwizard.app** on Mac OS X. On Windows you can also run DriverWizard from the **Start** menu: **Start | Programs | WinDriver | DriverWizard**.

2. If you are a registered user, make sure that your WinDriver license is registered (refer to Section 3.2, which explains how to install WinDriver and register your license).
   If you are an evaluation version user, you do not need to register a license.

3. For PCI cards – Insert your card into the PCI bus, and verify that DriverWizard detects it.

4. For ISA cards (Windows and Linux) – Insert your card into the ISA bus, configure DriverWizard with your card's resources and try to read/write to the card using DriverWizard.

© Jungo Ltd. 2005–2011

3.4.2. Windows CE Installation Check

1. Copy the console-mode Debug Monitor utility – **WinDriver\util\wddebug\<TARGET_CPU>\wddebug.exe** – from the host Windows machine to a directory on your target Windows CE device.

2. Run the Debug Monitor with the **`status`** command on the target device:
   `wddebug.exe status`
   If the windriver installation was successful, the application will display information regarding the Debug Monitor version and current status, the running WinDriver kernel module, and general system information.

3.5. Uninstalling WinDriver

This section will help you to uninstall either the evaluation or registered version of WinDriver.

3.5.1. Windows WinDriver Uninstall Instructions

- You can select to use the graphical **wdreg_gui.exe** utility instead of **wdreg.exe**.
- **wdreg.exe** and **wdreg_gui.exe** are found in the **WinDriver\util** directory (see Chapter 13 for details regarding these utilities).

1. Close any open WinDriver applications, including DriverWizard, the Debug Monitor, and user-specific applications.

2. If you created a Kernel PlugIn driver [11], uninstall and erase it:

   a. If your Kernel PlugIn driver is currently installed, uninstall it using the **wdreg** utility:
   `wdreg -name <Kernel PlugIn name> uninstall`

   The Kernel PlugIn driver name should be specified without the *.sys extension.

   b. Erase your Kernel PlugIn driver from the **%windir%\system32\drivers** directory.

3. Uninstall all Plug-and-Play devices (USB/PCI/PCMCIA) that have been registered with WinDriver via an INF file:

   - Uninstall the device using the **wdreg** utility:
     `wdreg -inf <path to the INF file> uninstall`
   - Verify that no INF files that register your device(s) with WinDriver's kernel module (**windrvr6.sys**) are found in the **%windir%\inf** directory.

4. Uninstall WinDriver:

   - **On the development PC**, on which you installed the WinDriver toolkit:
     Run **Start | WinDriver | Uninstall** , **OR** run the **uninstall.exe** utility from the **WinDriver** installation directory.

     The uninstall will stop and unload the WinDriver kernel module (**windrvr6.sys**); delete the copy of the **windrvr6.inf** file from the **%windir%\inf** directory; delete WinDriver from Windows' **Start** menu; delete the **WinDriver** installation directory (except for files that you added to this directory); and delete the shortcut icons to the DriverWizard and Debug Monitor utilities from the Desktop.

   - **On a target PC**, on which you installed the WinDriver kernel module (**windrvr6.sys**), but not the entire WinDriver toolkit:
     Use the **wdreg** utility to stop and unload the driver:
     ```
     wdreg -inf <path to windrvr6.inf> uninstall
     ```

     When running this command, **windrvr6.sys** should reside in the same directory as **windrvr6.inf**.

     (On the development PC, the relevant **wdreg** uninstall command is executed for you by the uninstall utility).

   - If you attempt to uninstall WinDriver while there are open handles to the WinDriver service (**windrvr6.sys** or your renamed driver [15.2], or there are connected and enabled Plug-and-Play devices that are registered to work with this service, **wdreg** will fail to uninstall the driver. This ensures that you do not uninstall the driver while it is being used.

   - You can check if the WinDriver kernel module is loaded by running the Debug Monitor utility (**WinDriver\util\wddebug_gui.exe**) [6.2]. When the driver is loaded, the Debug Monitor log displays driver and OS information; otherwise, it displays a relevant error message. On the development PC, the uninstall command will delete the Debug Monitor executables; to use this utility after the uninstallation, create a copy of **wddebug_gui.exe** before performing the uninstall procedure.

5. If **windrvr6.sys** was successfully unloaded, erase the following files (if they exist):

   - **%windir%\system32\drivers\windrvr6.sys**
   - **%windir%\inf\windrvr6.inf**
   - **%windir%\system32\wdapi1040.dll**
   - **%windir%\sysWOW64\wdapi1040.dll** (Windows x64)

6. Reboot the computer.

© Jungo Ltd. 2005–2011

3.5.2. Mac OS X WinDriver Uninstall Instructions

1. Close any open WinDriver applications, including DriverWizard, the Debug Monitor, and user-specific applications.

2. If you created a Kernel PlugIn driver [11], uninstall and erase it:

   a. If your Kernel PlugIn driver is currently installed, uninstall it using the OS's **kextunload** utility:
   ```
   $ sudo kextunload <full path to the Kernel PlugIn kernel extension>
   ```

   b. Erase your Kernel PlugIn driver's kernel extension from the **/System/Library/Extensions** folder, if it has been copied to this folder.

3. If you renamed the WinDriver kernel module [15.2], uninstall and erase it:

   a. Uninstall the renamed driver using the OS's **kextunload** utility:
   ```
   $ sudo kextunload <full path to the renamed WinDriver kernel extension>
   ```

   b. Erase the renamed driver's kernel extension from the **/System/Library/Extensions** folder, if it has been copied to this folder.

4. Uninstall WinDriver by running the **wd_uninstaller.sh** WinDriver uninstallation script, provided in the <**path to WinDriver**>/**util** folder:
   ```
   $ sudo <path to WinDriver>/util/wd_uninstaller.sh
   ```

© Jungo Ltd. 2005–2011

3.5.3. Linux WinDriver Uninstall Instructions

The following commands must be executed with root privileges.

1. Verify that the WinDriver driver module is not being used by another program:
   - View the list of modules and the programs using each of them:
     `/# /sbin/lsmod`
   - Identify any applications and modules that are using the WinDriver driver module. (By default, WinDriver module names begin with **windrvr6**).
   - Close any applications that are using the WinDriver driver module.
   - Unload any modules that are using the WinDriver driver module:
     `/# /sbin/modprobe -r <module_name>`
2. Unload the WinDriver driver module:
   `/# /sbin/modprobe -r windrvr6`
3. If you are not using a Linux 2.6.x kernel that supports the **udev** file system, remove the old device node in the /**dev** directory:
   `/# rm -f /dev/windrvr6`
4. If you created a Kernel PlugIn driver, remove it as well.
5. Remove the file **.windriver.rc** from the /**etc** directory:
   `/# rm -f /etc/.windriver.rc`
6. Remove the file **.windriver.rc** from **$HOME**:
   `/# rm -f $HOME/.windriver.rc`
7. If you created a symbolic link to DriverWizard, remove the link using the command
   `/# rm -f /usr/bin/wdwizard`
8. Remove the WinDriver installation directory using the command
   `/# rm -rf ~/WinDriver`
9. Remove the WinDriver shared object file, if it exists:
   /usr/lib/libwdapi1040.so (32-bit x86 or 32-bit PowerPC) /
   /usr/lib64/libwdapi1040.so (64-bit x86).

© Jungo Ltd. 2005–2011

Chapter 4
Using DriverWizard

This chapter describes WinDriver DriverWizard's hardware diagnostics and driver code generation capabilities.

CardBus devices are handled via WinDriver's PCI API; therefore *PCI* references in this chapter apply also to CardBus, on the operating systems on which it is supported [1.1].

4.1. An Overview

DriverWizard (included in the WinDriver toolkit) is a GUI-based diagnostics and driver generation tool that allows you to write to and read from the hardware, before writing a single line of code. The hardware is diagnosed through a Graphical User Interface – memory ranges can be read, registers can be toggled and interrupts can be checked.

Once the device is operating to your satisfaction, DriverWizard creates the skeletal driver source code, with functions to access your hardware's resources.

If you are developing a driver for a device that is based on one of the enhanced-support PCI chipsets (PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656; Altera pci_dev_kit; Xilinx VirtexII and BMD design; AMCC S5933), we recommend that you read Chapter 7, which explains WinDriver's enhanced support for specific chipsets, before starting your driver development.

DriverWizard can be used to diagnose your hardware; on Windows it can also be used to generate an INF file for your hardware.

Avoid using DriverWizard to generate code for a device based on one of the supported PCI chipsets [7], as DriverWizard generates generic code which will have to be modified according to the specific functionality of the device in question. Preferably, use the complete source code libraries and sample applications (supplied in the package) tailored to the various PCI chipsets.

DriverWizard is an excellent tool for two major phases in your HW/Driver development:

- **Hardware diagnostics**: After the hardware has been built, insert the hardware into the appropriate bus slot on your machine, and use DriverWizard to verify that the hardware is performing as expected.

- **Code generation**: Once you are ready to build your code, let DriverWizard generate your driver code for you.

The code generated by DriverWizard is composed of the following elements:

- **Library functions** for accessing each element of your device's resources (memory ranges, I/O ranges, registers and interrupts).
- **A 32-bit diagnostics program** in console mode with which you can diagnose your device. This application utilizes the special library functions described above. Use this diagnostics program as your skeletal device driver.
- **A project workspace/solution** that you can use to automatically load all of the project information and files into your development environment.
  For Linux, DriverWizard generates the required makefile.

4.2. DriverWizard Walkthrough

To use DriverWizard:

1. **Attach your hardware to the computer:**
   Attach the card to the appropriate bus slot on your computer.
   Alternatively, you have the option to use DriverWizard to generate code for a virtual PCI device, without having the actual device installed, by selecting the **PCI Virtual Device** DriverWizard option (see information in Step 2). When selecting this option, DriverWizard will generate code for your *virtual PCI device*.

2. **Run DriverWizard and select your device:**

   a. Start DriverWizard – **<path to WinDriver>/wizard/wdwizard** or **/Applications/wdwizard.app** on Mac OS X. On Windows you can also run DriverWizard from the **Start** menu: **Start | Programs | WinDriver | DriverWizard**.

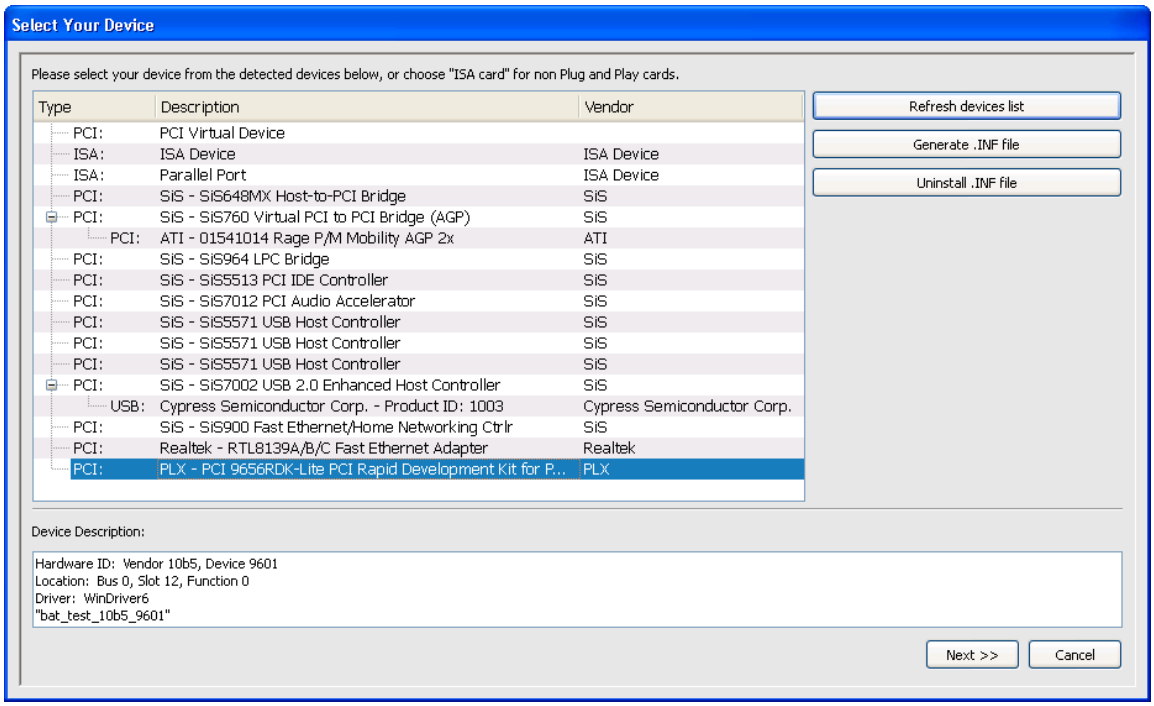
   On Windows 7 and Vista you must run DriverWizard as administrator.

   b. Click **New host driver project** to start a new project, or **Open an existing project** to open a saved session.

Figure 4.1. Create or Open a WinDriver Project

c. Select your **Plug-and-Play card** from the list of devices detected by DriverWizard.

Figure 4.2. Select Your Plug-and-Play Device


Select Your Device
Please select your device from the detected devices below, or choose "ISA card" for non Plug and Play cards.
Type
Description
Vendor
PCI: PCI Virtual Device
ISA: ISA Device — ISA Device
ISA: Parallel Port — ISA Device
PCI: SiS - SiS648MX Host-to-PCI Bridge — SiS
PCI: SiS - SiS760 Virtual PCI to PCI Bridge (AGP) — SiS
PCI: ATI - 01541014 Rage P/M Mobility AGP 2x — ATI
PCI: SiS - SiS964 LPC Bridge — SiS
PCI: SiS - SiS5513 PCI IDE Controller — SiS
PCI: SiS - SiS7012 PCI Audio Accelerator — SiS
PCI: SiS - SiS5571 USB Host Controller — SiS
PCI: SiS - SiS5571 USB Host Controller — SiS
PCI: SiS - SiS5571 USB Host Controller — SiS
PCI: SiS - SiS7002 USB 2.0 Enhanced Host Controller — SiS
USB: Cypress Semiconductor Corp. - Product ID: 1003 — Cypress Semiconductor Corp.
PCI: SiS - SiS900 Fast Ethernet/Home Networking Ctrlr — SiS
PCI: Realtek - RTL8139A/B/C Fast Ethernet Adapter — Realtek
PCI: PLX - PCI 9656RDK-Lite PCI Rapid Development Kit for P... — PLX
Refresh devices list
Generate .INF file
Uninstall .INF file
Device Description:
Hardware ID: Vendor 10b5, Device 9601
Location: Bus 0, Slot 12, Function 0
Driver: WinDriver6
"bat_test_10b5_9601"
Next >>
Cancel

For non-Plug-and-Play cards, select **ISA**.
To generate code for a PCI device that is not currently attached to the computer, select **PCI Virtual Device**.

When selecting the **PCI Virtual Device** option, DriverWizard allows you to define the device's resources. By specifying the I/O and/or Memory ranges, you may further define run-time registers (the offsets are relative to BARs). In addition, the IRQ must be specified if you want to generate code that acknowledges interrupts via run-time registers. Note, that the IRQ number and the size of the I/O and Memory ranges are irrelevant, since these will be automatically detected by DriverWizard when you install a physical device.

3. **Generate an INF file for DriverWizard**:
   On **Windows 7/Vista/Server 2008/Server 2003/XP**, the driver for Plug-and-Play devices (such as PCI and PCMCIA) is installed by installing an INF file for the device. DriverWizard enables you to generate an INF file that registers your device to work with WinDriver (i.e., with the **windrvr6.sys** driver). The INF file generated by DriverWizard should later be distributed to your customers who are using Windows 7 / Vista / Server 2008 / Server 2003 / XP, and installed on their PCs.

   The INF file that you generate in this step is also designed to enable DriverWizard to diagnose your device on Windows 7 / Vista / Server 2008 / Server 2003 / XP (for example, when no driver is installed for your PCI/PCMCIA device). Additional information concerning the need for an INF file is provided in Section 15.1.1.

   If you do not need to generate an INF file (e.g., if you are using DriverWizard on Linux), skip this step and proceed to the next one.

   To generate the INF file with DriverWizard, follow the steps below:

   a. In the **Select Your Device** screen, click the **Generate .INF file** button or click **Next** .

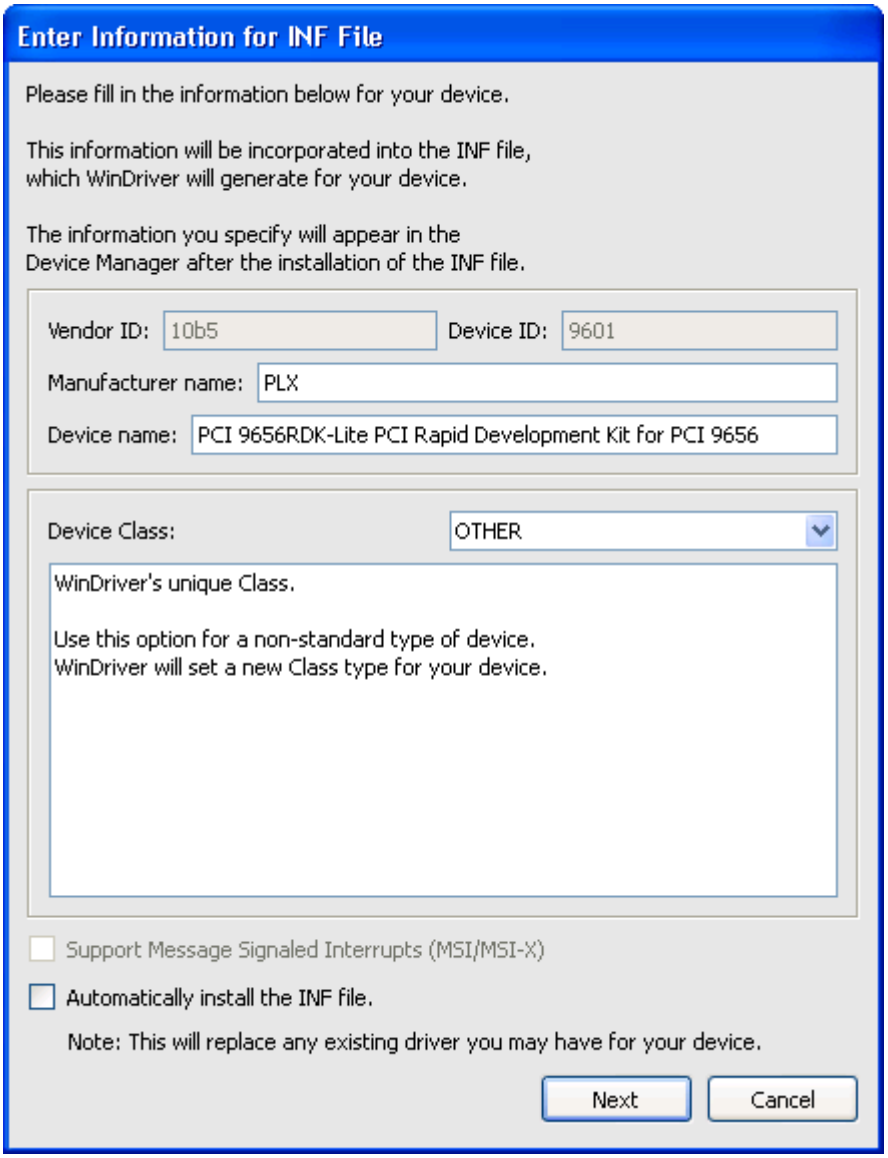
   b. DriverWizard will display information detected for your device – Vendor ID, Device ID, Device Class, manufacturer name and device name – and allow you to modify this information, as demonstrated in Figure 4.3 below.

   c. When you are done, click **Next** and choose the directory in which you wish to store the generated INF file. DriverWizard will then automatically generate the INF file for you.

      You can choose to automatically install the INF file by checking the **Automatically Install the INF file** option in the DriverWizard's INF generation dialogue.
      If the automatic INF file installation fails, DriverWizard will notify you and provide manual installation instructions (refer also the manual INF file installation instructions in Section 15.1).

© Jungo Ltd. 2005–2011

Figure 4.3. DriverWizard INF File Information


Enter Information for INF File
Please fill in the information below for your device.
This information will be incorporated into the INF file,
which WinDriver will generate for your device.
The information you specify will appear in the
Device Manager after the installation of the INF file.
Vendor ID:
10b5
Device ID:
9601
Manufacturer name:
PLX
Device name:
PCI 9656RDK-Lite PCI Rapid Development Kit for PCI 9656
Device Class:
OTHER
WinDriver's unique Class.
Use this option for a non-standard type of device.
WinDriver will set a new Class type for your device.
Support Message Signaled Interrupts (MSI/MSI-X)
Automatically install the INF file.
Note: This will replace any existing driver you may have for your device.
Next
Cancel

Handling of PCI Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) requires specific configuration in the device's INF file, as explained in Section 9.2.6.1 of the manual.
On Windows Vista and higher, if your hardware supports MSI or MSI-X, the **Support Message Signaled Interrupts** option in the DriverWizard's INF generation dialogue will be enabled and checked by default. When this option is checked, the generated DriverWizard INF file for your device will include support for MSI/MSI-X handling. However, when this option is not checked, PCI interrupts will be handled using the legacy level-sensitive interrupts method, regardless of whether the hardware and OS support MSI/MSI-X.

d. When the INF file installation completes, select and open your device from the list in the **Select Your Device** screen.

4. **Uninstall the INF file of your device:**
   You can use the **Uninstall** option to uninstall the INF file of your Plug-and-Play device (PCI/PCMCIA). Once you uninstall the INF file, the device will no longer be registered to work with the **windrvr6.sys**, and the INF file will be deleted from the Windows root directory.

   If you do not need to uninstall an INF file, skip this step and proceed to the next one.

   a. In the **Select Your Device** screen, click the **Uninstall .INF file** button.

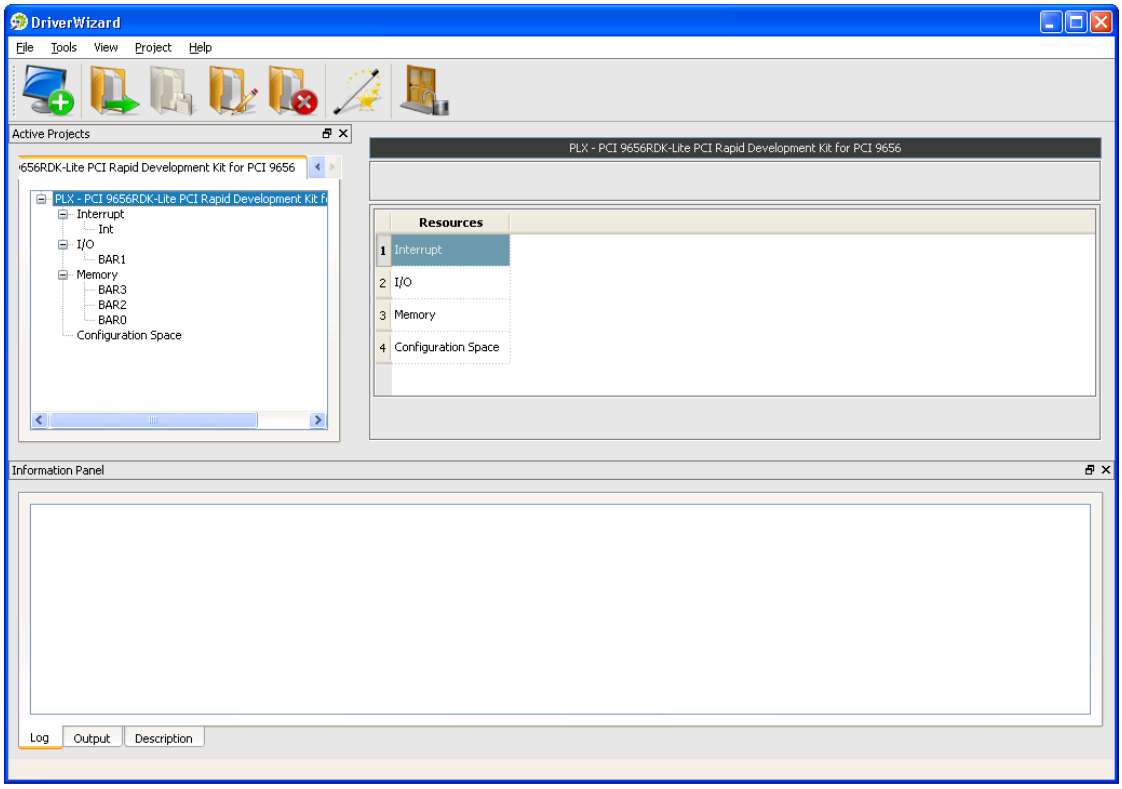
   b. Select the INF file to be removed.

5. **Diagnose your device:**
   Before writing your device driver, it is important to make sure your hardware is working as expected. Use DriverWizard to diagnose your hardware. All of your activity will be logged in the DriverWizard log so that you may later analyze your tests:

   a. Define and test your device's I/O and memory ranges, registers and interrupts:

   - DriverWizard will automatically detect your Plug-and-Play hardware resources: I/O ranges, memory ranges, and interrupts.

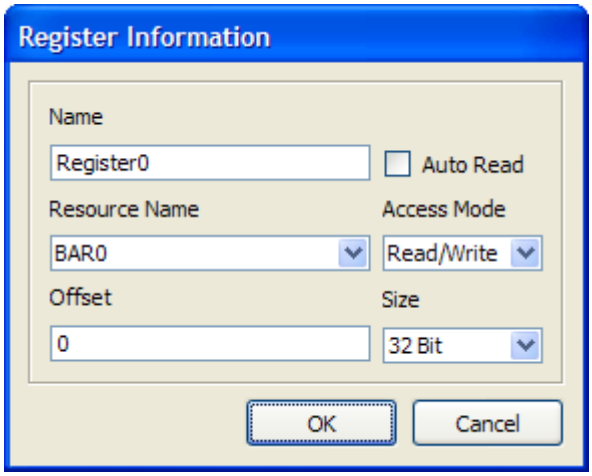
Figure 4.4. PCI Resources



For non-Plug-and-Play hardware, define your hardware's resources manually.

You can also manually define hardware registers, as demonstrated in Figure 4.5 below.

Figure 4.5. Define Registers



When defining registers, you may check the **Auto Read** box in the **Register Information** window. Registers marked as **Auto Read** will automatically be read for any register read/write operation performed from DriverWizard. The read results will be displayed in the wizard's Log window.

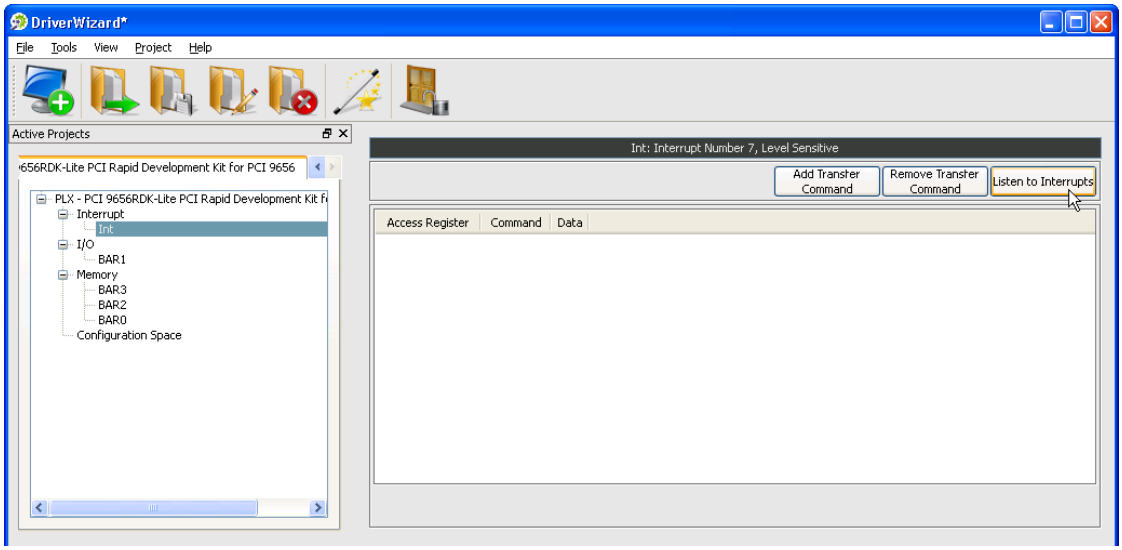
- Read and write to the I/O ports, memory space and your defined registers, as demonstrated in Figure 4.6.

When accessing memory mapped ranges, be aware that **Linux PowerPC** uses big-endian for handling memory storage, as opposed to the PCI bus that uses little-endian. For more information regarding little/big-endian issues, refer to Section 9.3.

Figure 4.6. Read/Write Memory and I/O

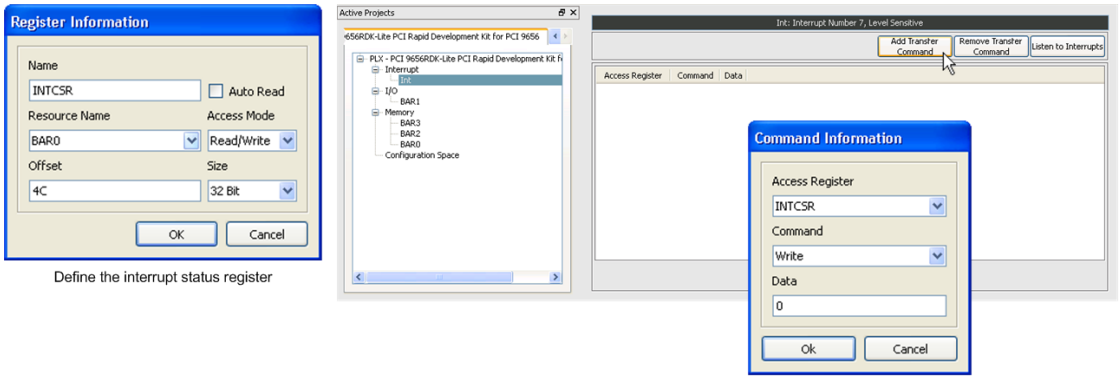
- 'Listen' to your hardware's interrupts.

Figure 4.7. Listen to Interrupts



For level-sensitive interrupts, such as legacy PCI interrupts, you must use DriverWizard to define the interrupt status register and assign the read/write command(s) for acknowledging (clearing) the interrupt, before attempting to listen to the interrupts with the wizard, otherwise the OS may hang! Figure 4.8 below demonstrates how to define an interrupt acknowledgment command for a defined `INTCSR` hardware register. Note, however, that interrupt acknowledgment information is hardware-specific.

Figure 4.8. Define Transfer Commands for Level-Sensitive Interrupts



Define the interrupt status register

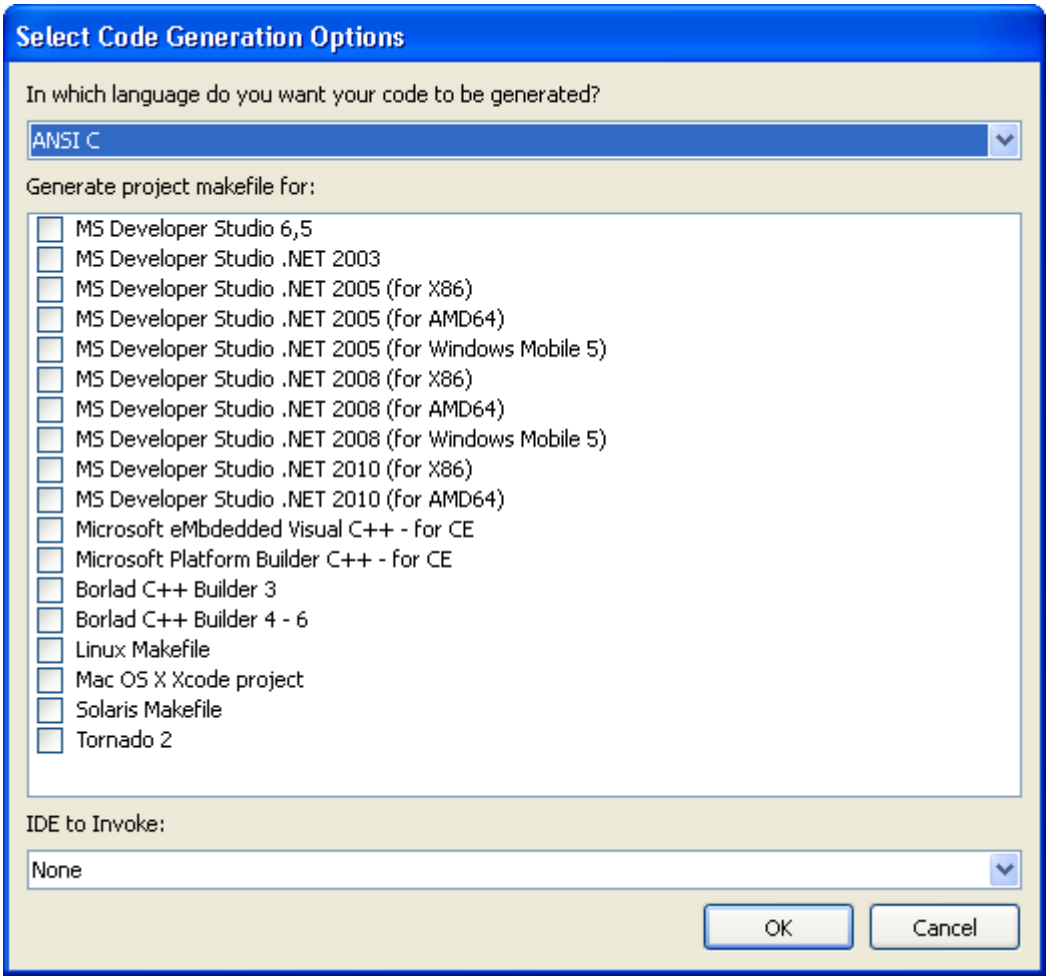
Define the transfer commands for acknowledging (clearing) the level sensitive interrupt

6. **Generate the skeletal driver code:**

   a. Select to generate code either via the **Generate Code** toolbar icon or from the **Project | Generate Code** menu.

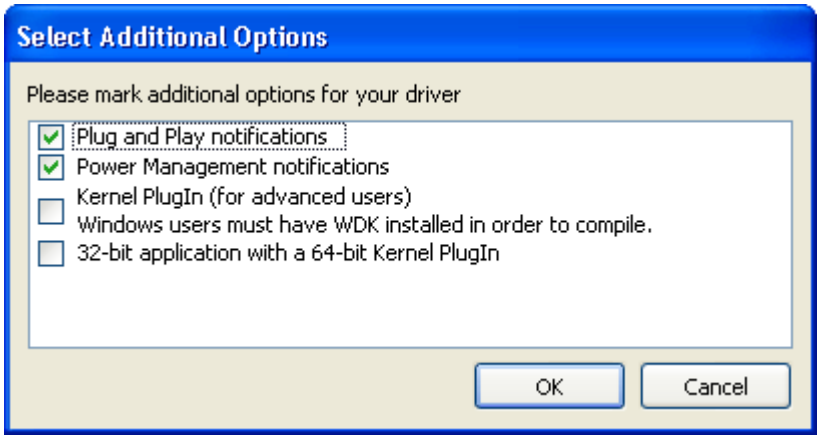
   b. In the **Select Code Generation Options** dialogue box that will appear, choose the code language and development environment(s) for the generated code and select **Next** to generate the code.

Figure 4.9. Code Generation Options


Select Code Generation Options
In which language do you want your code to be generated?
ANSI C
Generate project makefile for:
MS Developer Studio 6,5
MS Developer Studio .NET 2003
MS Developer Studio .NET 2005 (for X86)
MS Developer Studio .NET 2005 (for AMD64)
MS Developer Studio .NET 2005 (for Windows Mobile 5)
MS Developer Studio .NET 2008 (for X86)
MS Developer Studio .NET 2008 (for AMD64)
MS Developer Studio .NET 2008 (for Windows Mobile 5)
MS Developer Studio .NET 2010 (for X86)
MS Developer Studio .NET 2010 (for AMD64)
Microsoft eMbdedded Visual C++ - for CE
Microsoft Platform Builder C++ - for CE
Borlad C++ Builder 3
Borlad C++ Builder 4 - 6
Linux Makefile
Mac OS X Xcode project
Solaris Makefile
Tornado 2
IDE to Invoke:
None
OK
Cancel

c. Click **Next** and indicate whether you wish to handle Plug-and-Play and power management events from within your driver code, and whether you wish to generate Kernel PlugIn code [11].

Figure 4.10. Additional Driver Options


Select Additional Options
Please mark additional options for your driver
Plug and Play notifications
Power Management notifications
Kernel PlugIn (for advanced users)
Windows users must have WDK installed in order to compile.
32-bit application with a 64-bit Kernel PlugIn
OK
Cancel

Kernel PlugIn Windows Project Notes

- To compile the generated Kernel PlugIn code, the Windows Driver Kit (WDK) must be installed.
- To successfully build a Kernel PlugIn project using MS Visual Studio, the path to the project directory must not contain any spaces.

d. Save your project (if required) and click **OK** to open your development environment with the generated driver.

7. **Compile and run the generated code:**

   - Use this code as a starting point for your device driver. Modify where needed to perform your driver's specific functionality.
   - The source code DriverWizard creates can be compiled with any 32-bit compiler, and will run on all supported platforms without modification.

   For detailed compilation instructions, refer to Section 4.2.2.

4.2.1. Automatic Code Generation

After you have finished diagnosing your device and have ensured that it runs according to your specifications, you are ready to write your driver.

4.2.1.1. Generating the Code

Generate code by selecting this option either via DriverWizard's **Generate Code** toolbar icon or from the wizard's **Project | Generate Code** menu. DriverWizard will generate the source code for your driver, and place it along with the project file (**xxx.wdp**, where "xxx" is the project name). The files are saved in a directory DriverWizard creates for every development environment and operating system selected in the code generation dialogue box.

4.2.1.2. The Generated PCI/PCMCIA/ISA C Code

In the source code directory you now have a new **xxx_lib.h** file, which contains type definitions and functions declarations for the API created for you by the DriverWizard, and an **xxx_lib.c** source file, which contains the implementation of the generated device-specific API.
In addition, you will find an **xxx_diag.c** source file, which includes a `main`() function and implements a sample diagnostics application that utilizes the generated DriverWizard API to communicate with your device.

© Jungo Ltd. 2005–2011

The code generated by DriverWizard is composed of the following elements and files, where **xxx** represents your DriverWizard project name:

- Library functions for accessing each element of your card's resources (memory ranges and I/O, registers and interrupts):
  - **xxx_lib.c** Here you can find the implementation of the hardware-specific API (declared in **xxx_lib.h**), using the WinDriver Card (WDC) API [B.2].
  - **xxx_lib.h** Header file that contains type definitions and function declarations for the API implemented in the **xxx_lib.c** source file.
    You should include this file in your source code in order to use the API generated by DriverWizard for your device.
- A diagnostics program that utilizes the generated DriverWizard API (declared in **xxx_lib.h**) to communicate with your device(s):
  - **xxx_diag.c** The source code of the generated diagnostics console application.
    Use this diagnostics program as your skeletal device driver.
- A list of all files created can be found at **xxx_files.txt**.

After creating your code, compile it with your favorite compiler, and see it work!

Change the function `main`() of the program so that the functionality suits your needs.

4.2.1.3. The Generated Visual Basic and Delphi Code

The generated DriverWizard Visual Basic and Delphi code includes similar functions and provides similar functionality as the generated C code described in Section 4.2.1.2.

The generated Delphi code implements a console application (like the C code), while the Visual Basic code implements a GUI application.

4.2.1.4. The Generated C# Code

The generated DriverWizard C# code provides similar functionality as the generated C code [4.2.1.2], but from a GUI .NET program.

4.2.2. Compiling the Generated Code

4.2.2.1. Windows and Windows CE Compilation

As explained above, on Windows you can select to generate project and workspace/solution files for any of the supported integrated development environments (IDEs) – MS Visual Studio 5.0/6.0/2003/2005/2008/2010, Borland C++ Builder, Visual Basic 6.0, Borland Delphi, MS eMbedded Visual C++, or MS Platform Builder – and you can also select to automatically invoke your selected IDE from the wizard. You can then proceed to immediately build and run the code from your IDE.

You can also build the generated code from any other IDE that supports the selected code language and target OS. Simply create a new project file for your selected IDE, then add the generated source files to your project and compile and run the code.

- For **Windows 7/Vista/Server 2008/Server 2003/XP**, the generated IDE files are located under an **x86** directory – for 32-bit projects, or **amd64** directory – for 64-bit projects.
- For Windows CE, note that the generated **Windows Mobile** code is targeted at the Windows Mobile 5.0/6.0 ARMV4I SDK.

To build a Kernel PlugIn project (on Windows), follow the instructions in Section 12.7.1.

4.2.2.2. Mac OS X Compilation

As explained above, you can use DriverWizard to generate an Xcode project and a related makefile. You can easily build the generated code using either of the following methods:

In the following instructions, **<project_dir>** signfies the path to the location in which you saved your project (for example, **~/WinDriver/wizard/my_projects/JungoDriver**), and **xxx** signfies your selected project name (for example, **JungoDriver**).

- Use Xcode to open the generated Xcode project – **<project_dir>/macos/xxx.xcodeproj** (for example, **~/WinDriver/wizard/my_projects/JungoDriver/macos/JungoDriver.xcodeproj**) – and build the code.
- Open a command-line prompt, change directory to the **<project_dir>/macos** directory (for example, **~/WinDriver/wizard/my_projects/JungoDriver/macos**), and run `make` to build the code.

The build will create an **xxx** application under a **<project_dir>/macos/build/Release** or **<project_dir>/macos/build/Debug** subdirectory – depending on how you selected to build the project (for example, **~/WinDriver/wizard/my_projects/JungoDriver/macos/build/Release/JungoDriver**).

© Jungo Ltd. 2005–2011

You can also build the generated code using any other IDE/compiler that is supported on Mac OS X. Simply create a new project or make file for your selected IDE/compiler, add the generated source files to your project/makefile, and build the code.

To build a Kernel PlugIn project, follow the instructions in Section 12.7.2.

4.2.2.3. Linux Compilation

Use the makefile that was created for you by DriverWizard in order to build the generated code using your favorite compiler, preferably GCC.

To build a Kernel PlugIn project, follow the instructions in Section 12.7.3.

Chapter 5
Developing a Driver

This chapter takes you through the WinDriver driver development cycle.

If your device is based on one of the chipsets for which WinDriver provides enhanced support (PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656; Altera pci_dev_kit; Xilinx VirtexII and BMD design; AMCC S5933), read the following overview and then skip straight to Chapter 7.

5.1. Using DriverWizard to Build a Device Driver

- Use DriverWizard to diagnose your card: Read/write the I/O and memory ranges, view the PCI configuration registers information, define registers for your card and read/write the registers, and listen to interrupts.

- Use DriverWizard to generate skeletal code for your device in C, C#, Delphi (Pascal), or Visual Basic 6.0. For more information about DriverWizard, refer to Chapter 4.

- If you are using one of the specific chipsets for which WinDriver offers enhanced support (PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656; Altera pci_dev_kit; Xilinx VirtexII and BMD design; AMCC S5933), we recommend that you use the specific sample code provided for your chip as your skeletal driver code. For more details regarding WinDriver's enhanced support for specific chipsets, refer to Chapter 7.

- Use any C / .NET / Delphi / Visual Basic compiler/IDE (such as MS Visual Studio, Borland C++ Builder, Borland Delphi, Visual Basic 6.0, MS eMbedded Visual C++, MS Platform Builder C++, Xcode, GCC) to compile the skeletal driver you need.

- For Linux, use any compilation environment, preferably GCC, to build your code.

- That is all you need to do in order to create your user-mode driver.
  If you discover that better performance is needed, please refer to Chapter 10 for details on performance improvement.

Please see Appendix B for a detailed description of WinDriver's PCI/ISA/CardBus API.

To learn how to perform operations that DriverWizard cannot automate, refer to Chapter 9 of the manual.

5.2. Writing the Device Driver Without DriverWizard

There may be times when you choose to write your driver directly, without using DriverWizard. In such cases, either follow the steps outlined in this section to create a new driver project, or use one of the WinDriver samples, which most closely resembles your target driver, and modify the sample to suit your specific requirements.

5.2.1. Include the Required WinDriver Files

1. Include the relevant WinDriver header files in your driver project.
   All header files are found under the **WinDriver/include** directory.

   On Mac OS X, when using the WDAPI framework, the header files include path is **/Library/Frameworks/WDAPI.framework/Headers**.

   All WinDriver projects require the **windrvr.h** header file.
   When using the `WDC_xxx` API [B.2], include the **wdc_lib.h** and **wdc_defs.** header files (these files already include **windrvr.h**).

   Include any other header file that provides APIs that you wish to use from your code (e.g., files from the **WinDriver/samples/shared** directory, which provide convenient diagnostics functions.)

2. Include the relevant header files from your source code: For example, to use API from the **windrvr.h** header file, add the following line to the code:

   ```
   #include "windrvr.h"
   ```

3. Link your code with the WDAPI library (Windows) / framework (Mac OS X) / shared object (Linux):

   - For Windows 7/Vista/Server 2008/Server 2003/XP: **WinDriver\lib\<CPU>\wdapi1040.lib** or **wdapi1040_borland.lib** (for Borland C++ Builder), where the **<CPU>** directory is either **x86** (32-bit binaries for x86 platforms), **amd64** (64-bit binaries for x64 platforms) or **amd64\x86** (32-bit binaries for x64 platforms [A.2]

   - For Windows CE: **WinDriver\lib\WINCE\<CPU>\wdapi1040.lib**

   - For Mac OS X: **/Library/Frameworks/WDAPI.framework**

   - For Linux: From the **WinDriver/lib** directory – **libwdapi1040.so** or **libwdapi1040_32.so** (for 32-bit applications targeted at 64-bit platforms)
     Note: When using **libwdapi1040_32.so**, first create a copy of this file in a different directory and rename it to **libwdapi1040.so**, then link your code with the renamed file [A.2].

© Jungo Ltd. 2005–2011

You can also include the library's source files in your project instead of linking the project with the library. The C source files are located under the **WinDriver/src/wdapi** directory.

When linking your project with the WDAPI library/framework/shared object, you will need to distribute this binary with your driver.
For Windows, get **wdapi1040.dll** / **wdapi1040_32.dll** (for 32-bit applications targeted at 64-bit platforms) from the **WinDriver\redist** directory.
For Mac OS X, get **WDAPI.framework** from the OS **/Library/Frameworks** directory.
For Linux, get **libwdapi1040.so** / **libwdapi1040_32.so** (for 32-bit applications targeted at 64-bit platforms) from the **WinDriver/lib** directory.

Note: On Windows and Linux, when using the DLL/shared object file for 32-bit applications on 64-bit platforms (**wdapi1040_32.dll** / **libwdapi1040_32.so**), rename the copy of the file in the distribution package, by removing the **_32** portion [A.2].
For detailed distribution instructions, refer to Chapter 14.

4. Add any other WinDriver source files that implement API that you which to use in your code (e.g., files from the **WinDriver/samples/shared** directory.)

5.2.2. Write Your Code

This section outlines the calling sequence when using the `WDC_xxx` API [B.2].

1. Call `WDC_DriverOpen`() [B.3.2] to open a handle to WinDriver and the WDC library, compare the version of the loaded driver with that of your driver source files, and register your WinDriver license (for registered users).

2. For PCI/CardBus/PCMCIA devices, call `WDC_PciScanDevices`() [B.3.4] / `WDC_PcmciaScanDevices`() [B.3.7] to scan the PCI/PCMCIA bus and locate your device.

3. For PCI/CardBus/PCMCIA devices, call `WDC_PciGetDeviceInfo`() [B.3.8] / `WDC_PcmciaGetDeviceInfo`() [B.3.9] to retrieve the resources information for your selected device.
   For ISA devices, define the resources yourself within a `WD_CARD` structure.

4. Call `WDC_PciDeviceOpen`() [B.3.10] / `WDC_PcmciaDeviceOpen`() [B.3.11] / `WDC_IsaDeviceOpen`() [B.3.12] (depending on your device), and pass to the function the device's resources information. These functions return a handle to the device, which you can later use to communicate with the device using the `WDC_xxx` API.

5. Communicate with the device using the `WDC_xxx` API (see the description in Appendix B).
   To enable interrupts, call `WDC_IntEnable`() [B.3.46].
   To register to receive notifications for Plug-and-Play and power management events, call `WDC_EventRegister`() [B.3.49].

6. When you are done, call `WDC_IntDisable()` [B.3.47] to disable interrupt handling (if previously enabled), call `WDC_EventRegister()` [B.3.49] to unregister Plug-and-Play and power management event handling (if previously registered), and then call `WDC_PciDeviceClose()` [B.3.13] / `WDC_PcmciaDeviceClose()` [B.3.14] / `WDC_IsaDeviceClose()` [B.3.15] (depending on your device) in order to close the handle to the device.

7. Call `WDC_DriverClose()` [B.3.3] to close the handles to WinDriver and the WDC library.

5.2.3. Configure and Build Your Code

After including the required files and writing your code, make sure that the required build flags and environment variables are set, then build your code.

Before building your code, verify that the `WD_BASEDIR` environment variable is set to the location of the of the WinDriver installation directory.
On Windows, Windows CE, and Linux you can define the `WD_BASEDIR` environment variable globally – as explained in Chapter 3: For Windows – refer to the Windows WD_BASEDIR note in Section 3.2.1; for Windows CE – refer to Section 3.2.2.3; for Linux: refer to Section 3.2.4.2, Step 9.
On Mac OS X, you need to add a `WD_BASEDIR` definition to each driver project. When generating code with DriverWizard [4], this is done automatically. To add this definition manually – open your project with Xcode, select **Project Info –> Build tab –> User Defines**, and add a `WD_BASEDIR` definition that points to your WinDriver installation directory.

5.3. Developing Your Driver on Windows CE Platforms

To use WinDriver to handle a Plug-and-Play device, you must first register the device with the WinDriver kernel module (**windrvr6.dll**).

To register the device with WinDriver, modify the registry to identify the device by its class (<*CLASS*>), subclass (<*SUBCLASS*>), vendor ID (<*VENDOR_ID*>), and device ID (<*DEVICE_ID*>) – as hexadecimal values – and link the device to **windrvr6.dll**. The registry can be modified by adding the relevant information to your **project.reg** file, as demonstrated below:

```
[HKEY_LOCAL_MACHINE\Drivers\BuiltIn\PCI\Template\WDCard]
  "Prefix"="WDR"
  "Dll"="windrvr6.dll"
  "Class"=dword:<CLASS>
  "SubClass"=dword:<SUBCLASS>
  "Order"=dword:ff
  "VendorID"=dword:<VENDOR_ID>
  "DeviceID"=dword:<DEVICE_ID>
  "IsrDll"="giisr.dll"
  "IsrHandler"="ISRHandler"
  "WdIntEnh"=dword:0
```

For information about the `WdIntEnh` registry setting and interrupt latency, see Section 9.2.8.1.

For more information about the relevant registry settings, refer to *PCI Bus Driver Registry Settings* in the MSDN Library.

5.4. Developing in Visual Basic and Delphi

The entire WinDriver API can be used when developing drivers in Visual Basic and Delphi.

5.4.1. Using DriverWizard

DriverWizard can be used to diagnose your hardware and verify that it is working properly before you start coding. You can then proceed to automatically generate source code with the wizard in a variety of languages, including Delphi and Visual Basic. For more information, refer to Chapter 4 and Section 5.4.4 below.

5.4.2. Samples

Samples for drivers written using the WinDriver API in Delphi or Visual Basic can be found in:

1. **WinDriver\delphi\samples**
2. **WinDriver\vb\samples**

Use these samples as a starting point for your own driver.

5.4.3. Kernel PlugIn

Delphi and Visual Basic cannot be used to create a Kernel PlugIn. Developers using WinDriver with Delphi or VB in user mode must use C when writing their Kernel PlugIn.

5.4.4. Creating your Driver

The method of development in Visual Basic is the same as the method in C using the automatic code generation feature of DriverWizard.

Your work process should be as follows:

- Use DriverWizard to easily diagnose your hardware.
- Verify that it is working properly.
- Generate your driver code.
- Integrate the driver into your application.
- You may find it useful to use the WinDriver samples to get to know the WinDriver API and as your skeletal driver code.

© Jungo Ltd. 2005–2011

Chapter 6
Debugging Drivers

The following sections describe how to debug your hardware-access application code.

6.1. User-Mode Debugging

- Since WinDriver is accessed from the user mode, we recommend that you first debug your code using your standard debugging software.
- The Debug Monitor utility [6.2] logs debug messages from WinDriver's kernel-mode and user-mode APIs. You can also use WinDriver APIs to send your own debug messages to the Debug Monitor log.
- When using WinDriver's API (such as `WD_Transfer`() – see the **WinDriver PCI Low-Level API Reference**), to read/write memory ranges on the card in the kernel, while the Debug Monitor [6.2] is activated, WinDriver's kernel module validates the memory ranges, i.e., it verifies that the reading/writing from/to the memory is in the range that is defined for the card.
- Use DriverWizard to check values of memory and registers in the debugging process.

6.2. Debug Monitor

Debug Monitor is a powerful graphical- and console-mode tool for monitoring all activities handled by the WinDriver kernel.
You can use this tool to monitor how each command sent to the kernel is executed.

In addition, WinDriver enables you to print your own debug messages to the Debug Monitor, using the `WD_DebugAdd`() function (described in the **WinDriver PCI Low-Level API Reference**) or the high-level `PrintDbgMessage`() function [B.8.14].

The Debug Monitor comes in two versions:

- **wddebug_gui** [6.2.1] – a GUI version for Windows 7/Vista/Server 2008/Server 2003/XP, Mac OS X, and Linux.
- **wddebug** [6.2.2] – a console-mode version for Windows, Windows CE, Mac OS X, and Linux; on Windows CE, **wddebug** also supports GUI execution.

Both Debug Monitor versions are provided in the **WinDriver/util** directory; on Mac OS X, the GUI version is provided at **/Applications/wddebug_gui.app**.

© Jungo Ltd. 2005–2011

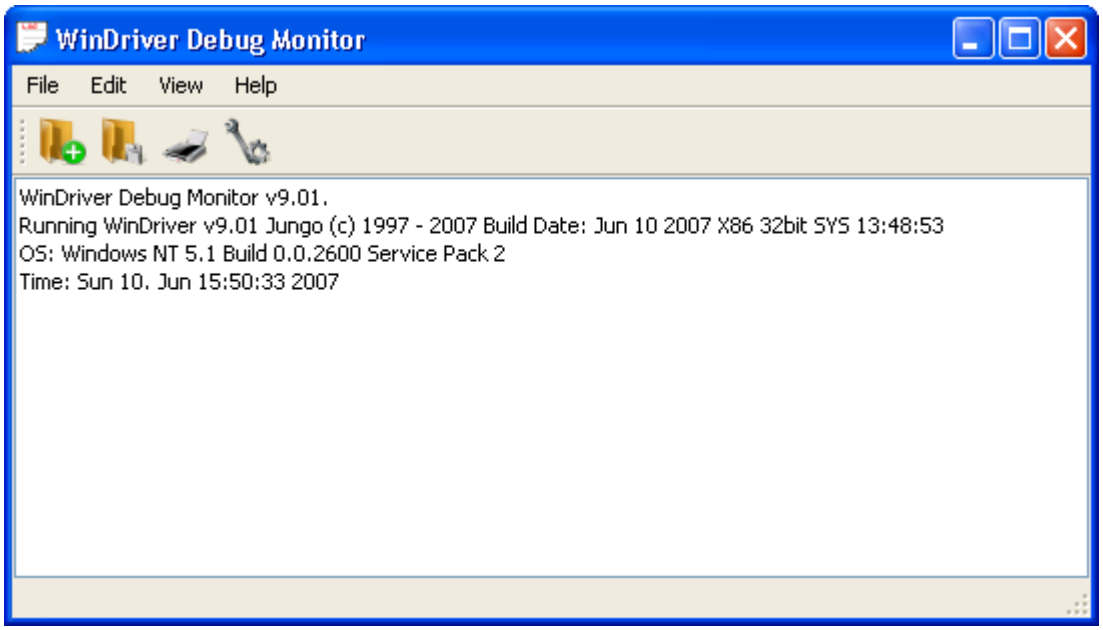
6.2.1. The wddebug_gui Utility

wddebug_gui is a fully graphical (GUI) version of the Debug Monitor utility for Windows 7/ Vista/Server 2008/Server 2003/XP and Linux.

1. Run the Debug Monitor using either of the following methods:

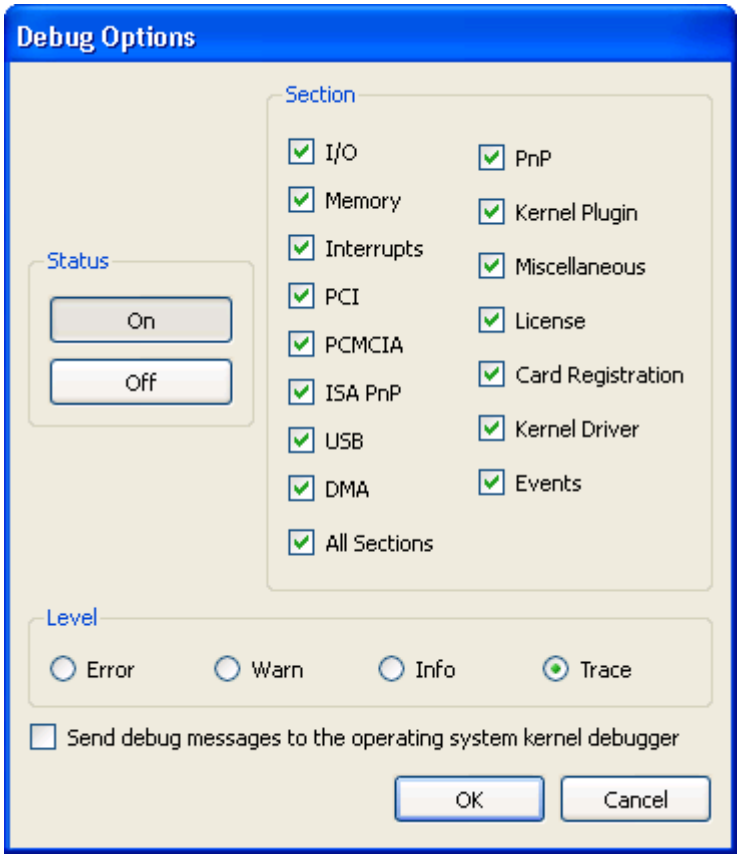
   - Run **WinDriver/util/wddebug_gui**, or **/Applications/wddebug_gui.app** on Mac OS X.
   - Run the Debug Monitor from DriverWizard's **Tools** menu.
   - On Windows, run **Start | Programs | WinDriver | Debug Monitor**.

Figure 6.1. Start Debug Monitor


WinDriver Debug Monitor
File
Edit
View
Help
WinDriver Debug Monitor v9.01.
Running WinDriver v9.01 Jungo (c) 1997 - 2007 Build Date: Jun 10 2007 X86 32bit SYS 13:48:53
OS: Windows NT 5.1 Build 0.0.2600 Service Pack 2
Time: Sun 10. Jun 15:50:33 2007

2. Set the Debug Monitor's status, trace level and debug sections information from the **Debug Options** dialogue, which is activated either from the Debug Monitor's **View | Debug Options** menu or the **Debug Options** toolbar button.

Figure 6.2. Debug Options



- **Status** – Set trace on or off.
- **Section** – Choose what part of the WinDriver API you would like to monitor.

  For example, if you are experiencing problems with the interrupt handler on your PCI card, select the **PCI** and **Interrupts** sections.

  Choose carefully those sections that you would like to monitor. Checking more options than necessary could result in an overflow of information, making it harder for you to locate your problem.

- **Level** – Choose the level of messages you want to see for the resources defined.
  - **Error** is the lowest trace level, resulting in minimum output to the screen.
  - **Trace** is the highest trace level, displaying every operation the WinDriver kernel performs.
- **Send debug messages to the operating system kernel debugger** –

  Select this option to send the debug messages received from the WinDriver kernel module to an external kernel debugger, in addition to the Debug Monitor.

© Jungo Ltd. 2005–2011

On Windows 7 and Vista, the first time that you enable this option you will need to restart the PC.

A free Windows kernel debugger, WinDbg, is distributed with the Windows Driver Kit (WDK) and is part of the Debugging Tools for Windows package, distributed via the Microsoft web site.

3. Once you have defined what you want to trace and on what level, click **OK** to close the **Debug Options** window.

4. Activate your application (step-by-step or in one run).

5. Watch the Debug Monitor log (or the kernel debugger log, if enabled) for errors or any unexpected messages.

6.2.1.1. Running wddebug_gui for a Renamed Driver

By default, **wddebug_gui** logs messages from the default WinDriver kernel module – **windrvr6.sys/.o/.ko** or **WinDriver.kext**. However, you can also use **wddebug_gui** to log debug messages from a renamed version of this driver [15.2], by running **wddebug_gui** from the command line with the **`driver_name`** option: **`wddebug_gui <driver_name>`**.
On Mac OS X, run

```
/Applications/wddebug_gui.app/Contents/MacOS/wddebug_gui \
  <driver_name>
```

The driver name should be set to the name of the driver file without the file's extension; e.g., **windrvr6**, not **windrvr6.sys** (on Windows) or **windrvr6.o** (on Linux).

For example, if you have renamed the default **windrvr6.sys** driver on Windows to **my_driver.sys**, you can log messages from your driver by running the Debug Monitor using the following command: **`wddebug_gui my_driver`**

6.2.2. The wddebug Utility

6.2.2.1. Console-Mode wddebug Execution

The **wddebug** version of the Debug Monitor utility can be executed as a console-mode application on all supported operating systems: Windows, Windows CE, Mac OS X, and Linux. To use the console-mode Debug Monitor version, run **WinDriver/util/wddebug** in the manner explained below.

For console-mode execution on Windows CE, start a command window (**CMD.EXE**) on the Windows CE target, and then run the program **WDDEBUG.EXE** inside this shell. You can also execute **wddebug** via the Windows CE GUI, as explained in Section 6.2.2.2.

wddebug console-mode usage

```
wddebug [<driver_name>] [<command>] [<level>]
[<sections>]
```

The **wddebug** arguments must be provided in the order in which they appear in the usage statement above.

- **`<driver_name>`**: The name of the driver to which to apply the command.

  The driver name should be set to the name of the WinDriver kernel module – **windrvr6** or **WinDriver** (on Mac OS X), or a renamed version of this driver (refer to the explanation in Section 15.2).

  The driver name should be set to the name of the driver file without the file's extension; for example, **windrvr6**, not **windrvr6.sys** (on Windows) or **windrvr6.o** (on Linux).

- **`<command>`**: The Debug Monitor command to execute:

  - Activation commands:

    - **`on`**: Turn the Debug Monitor on.

    - **`off`**: Turn the Debug Monitor off.

    - **`dbg_on`** : Redirect the debug messages from the Debug Monitor to a kernel debugger and turn the Debug Monitor on (if it was not already turned on).

      On Windows 7 and Vista, the first time that you enable this option you will need to restart the PC.

    - **`dbg_off`** : Stop redirecting debug messages from the Debug Monitor to a kernel debugger.

  The **`on`** and **`dbg_on`** commands can be run together with the **`<level>`** and **`<sections>`** options, described below.

  - **`dump`**: Continuously display ('dump') debug information, until the user selects to stop.

  - **`status`**: Display information regarding the running **`<driver_name>`** driver, the current Debug Monitor status – including the active debug level and sections (when the Debug Monitor is on) – and the size of the debug messages buffer.

  - **`help`** : Display usage instructions.

  - None: You can run **wddebug** with no arguments, including no command. On platforms other than Windows CE, this is equivalent to running **`wddebug help`**. On Windows CE, running **`wddebug`** with no arguments activates the utility's Windows CE GUI version, as explained in Section 6.2.2.2.

The following options are applicable only to the **on** and **dbg_on** commands:

- **<level>**: The debug trace level to set. The level can be set to either of the following flags: **ERROR**, **WARN**, **INFO** or **TRACE**, where ERROR is the lowest trace level and TRACE is the highest level (displays all messages).
  The default debug trace level is TRACE.

- **<sections>**: The debug sections to set. The debug sections determine what part of the WinDriver API you would like to monitor.

  For a full list of all supported debug sections, run **wddebug help** to view the utility's usage instructions.
  The default debug sections flag is **ALL** – sets all the supported debug sections.

Usage Sequence

To log messages using **wddebug**, use the following sequence:

- Turn on the Debug Monitor by running **wddebug** with either the **on** command, or the **dbg_on** command – which redirects the debug messages to a kernel debugger before turning on the Debug Monitor.

  You can use the **level** and/or **sections** flags to set the debug level and/or sections for the log. If these options are not explicitly set, the default values will be used.

  You can also log messages from a renamed WinDriver driver by preceding the command with the name of the driver (see the **<driver_name>** option above). The default driver name is **windrvr6** or **WinDriver** (on Mac OS X).

- Run **wddebug** with the **dump** command to begin dumping debug messages to the command prompt. You can turn off the display of the debug messages, at any time, by following the instructions displayed in the command prompt.

- Run applications that use the driver, and view the debug messages as they are being logged to the command prompt/the kernel debugger.

- You can run **wddebug** with the **status** command, at any time while the Debug Monitor is on, to view the current debug level and sections, as well as information regarding the running <**driver_name**> kernel module.

- You can use **dbg_on** and **dbg_off** to toggle the redirection of debug messages to a kernel debugger at any time while the Debug Monitor is on.

- When you are ready, turn off the Debug Monitor by running **wddebug** with the **off** command.

You can also run **wddebug** with the **status** command while the Debug Monitor is turned off, to view information regarding the running <**driver_name**> driver.

© Jungo Ltd. 2005–2011

EXAMPLE

The following is an example of a typical **wddebug** usage sequence. Since no **<driver_name>** is set, the commands are applied to the default driver – **windrvr6** or **WinDriver** (on Mac OS X).

- Turn the Debug Monitor on with the highest trace level for all sections:
  wddebug on TRACE ALL

  Note: This is the same as running **'wddebug on TRACE'**, since **ALL** is the default debug sections option.

- Dump the debug messages continuously, until the user selects to stop:
  wddebug dump

- Use the driver and view the debug messages in the command prompt.

- Turn the Debug Monitor off:
  wddebug off

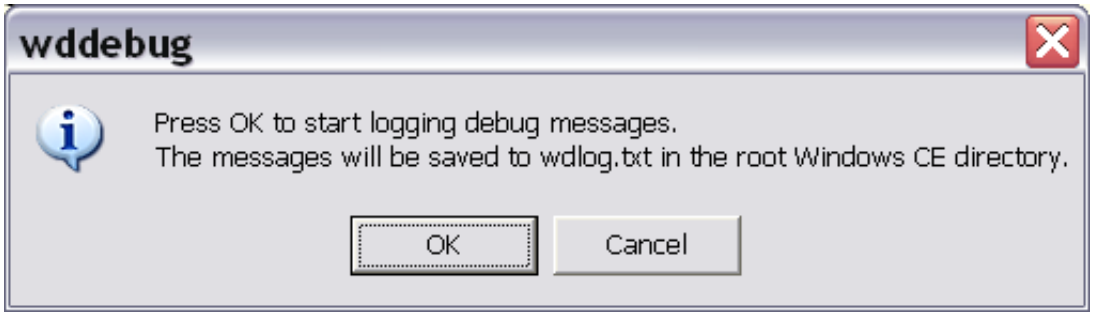
- Display usage instructions:
  wddebug help As explained above, on all platforms other than Windows CE, this is equivalent to running **wddebug** with no arguments.

6.2.2.2. Windows CE GUI wddebug Execution

On Windows CE, you can also log debug messages by running **wddebug** without any arguments. This method is designed to enable debug logging on Windows CE platforms that do not have a command-line prompt. On such platforms, you can activate debug logging by double-clicking the **wddebug** executable; this is equivalent to running the application with no arguments from a command-line prompt.

When executing **wddebug** without arguments, the user is informed, via a GUI message box, that log messages will be stored in a predetermined log file – **wdlog.txt** in the root Windows CE directory – and is given the option to cancel or continue.

Figure 6.3. wddebug Windows CE Start Log Message


wddebug
Press OK to start logging debug messages.
The messages will be saved to wdlog.txt in the root Windows CE directory.
OK
Cancel

If the user selects to continue, debug logging is turned on with a trace level of **TRACE** and debug sections **ALL**, and the Debug Monitor begins dumping debug messages to the **wdlog.txt** log file. The user can stop the logging and turn off debug logging, at any time, via a dedicated GUI message box.

Figure 6.4. wddebug Windows CE Stop Log Message

Chapter 7
Enhanced Support for Specific Chipsets

7.1. Overview

In addition to the standard WinDriver API and the DriverWizard code generation capabilities described in this manual, which support development of drivers for any PCI/ISA/PCMCIA/CardBus device, WinDriver offers enhanced support for specific PCI chipsets. The enhanced support includes custom API and sample diagnostics code, which are designed specifically for these chipsets.

WinDriver's enhanced support is currently available for the following chipsets: PLX 6466, 9030, 9050, 9052, 9054, 9056, 9080 and 9656; Altera pci_dev_kit; Xilinx VirtexII and BMD design; AMCC S5933.

7.2. Developing a Driver Using the Enhanced Chipset Support

When developing a driver for a device based on one of the enhanced-support chipsets [7.1], you can use WinDriver's chipset-set specific support by following these steps:

1. Locate the sample diagnostics program for your device under the **WinDriver/chip_vendor/chip_name** directory.

   Most of the sample diagnostics programs are named **xxx_diag** and their source code is normally found under an **xxx_diag** subdirectory. The program's executable is found under a subdirectory for your target operating system (e.g., **WIN32** for Windows.)

2. Run the custom diagnostics program to diagnose your device and familiarize yourself with the options provided by the sample program.

3. Use the source code of the diagnostics program as your skeletal device driver and modify the code, as needed, to suit your specific development needs. When modifying the code, you can utilize the custom WinDriver API for your specific chip. The custom API is typically found under the **WinDriver/chip_vendor/lib** directory.

© Jungo Ltd. 2005–2011

4. If the user-mode driver application that you created by following the steps above contains parts that require enhanced performance (e.g., an interrupt handler), you can move the relevant portions of your code to a Kernel PlugIn driver for optimal performance, as explained in Chapter 11.

Chapter 8
PCI Express

8.1. PCI Express Overview

The PCI Express (**PCIe**) bus architecture (formerly 3GIO or 3rd Generation I/O) was introduced by Intel, in partnership with other leading companies, including IBM, Dell, Compaq, HP and Microsoft, with the intention that it will become the prevailing standard for PC I/O in the years to come.

PCI-Express allows for larger bandwidth and higher scalability than the standard PCI 2.2 bus.

The standard PCI 2.2 bus is designed as a single parallel data bus through which all data is routed at a set rate. The bus shares the bandwidth between all connected devices, without the ability to prioritize between devices. The maximum bandwidth for this bus is 132MB/s, which has to be shared among all connected devices.

PCI Express consists of serial, point-to-point wired, individually clocked 'lanes', each lane consisting of two pairs of data lines that can carry data upstream and downstream simultaneously (full-duplex). The bus slots are connected to a switch that controls the data flow on the bus. A connection between a PCI Express device and a PCI Express switch is called a 'link'. Each link is composed of one or more lanes. A link composed of a single lane is called an x1 link; a link composed of two lanes is called an x2 link; etc. PCI Express supports x1, x2, x4, x8, x12, x16, and x32 link widths (lanes). The PCI Express architecture allows for a maximum bandwidth of approximately 500MB/s per lane. Therefore, the maximum potential bandwidth of this bus is 500MB/s for x1, 1,000MB/s for x2, 2,000MB/s for x4, 4,000MB/s for x8, 6,000MB/s for x12, and 8,000MB/s for x16. These values provide a significant improvement over the maximum 132MB/s bandwidth of the standard 32-bit PCI bus. The increased bandwidth support makes PCI Express ideal for the growing number of devices that require high bandwidth, such as hard drive controllers, video streaming devices and networking cards.

The usage of a switch to control the data flow in the PCI Express bus, as explained above, provides an improvement over a shared PCI bus, because each device essentially has direct access to the bus, instead of multiple components having to share the bus. This allows each device to use its full bandwidth capabilities without having to compete for the maximum bandwidth offered by a single shared bus. Adding to this the lanes of traffic that each device has access to in the PCI Express bus, PCI Express truly allows for control of much more bandwidth than previous PCI technologies. In addition, this architecture enables devices to communicate with each other directly (peer-to-peer communication).

In addition, the PCI Express bus topology allows for centralized traffic-routing and resource-management, as opposed to the shared bus topology. This enables PCI Express to support quality

of service (QoS): The PCI Express switch can prioritize packets, so that real-time streaming packets (i.e., a video stream or an audio stream) can take priority over packets that are not as time critical.

Another main advantage of the PCI Express is that it is cost-efficient to manufacture when compared to PCI and AGP slots or other new I/O bus solutions such as PCI-X.

PCI Express was designed to maintain complete hardware and software compatibility with the existing PCI bus and PCI devices, despite the different architecture of these two buses.

As part of the backward compatibility with the PCI 2.2 bus, legacy PCI 2.2 devices can be plugged into a PCI Express system via a PCI Express-to-PCI bridge, which translates PCI Express packets back into standard PCI 2.2 bus signals. This bridging can occur either on the motherboard or on an external card.

8.2. WinDriver for PCI Express

WinDriver fully supports backward compatibility with the standard PCI features on PCI Express boards. The wide support provided by WinDriver for the standard PCI bus – including a rich set of APIs, code samples and the graphical DriverWizard for hardware debugging and driver code generation – is also applicable to PCI Express devices, which by design are backward compatible with the legacy PCI bus.

You can also use WinDriver's PCI API to easily communicate with PCI devices connected to the PC via PCI Express-to-PCI bridges and switches (e.g., the PLX 8111/8114 bridges or the PLX 8532 switch, respectively).

In addition, WinDriver provides you with a set of APIs for easy access to the PCI Express extended configuration space on target platforms that support such access (e.g., Windows, Mac OS X, and Linux) – see the description of the `WDC_PciReadCfgXXX`() and `WDC_PciWriteCfgXXX`() functions in Sections B.3.27–B.3.34 of the present manual, or the description of the lower-level `WD_PciConfigDump`() function in the **WinDriver PCI Low-Level API Reference**.

On Linux, Mac OS X, and Windows Vista and higher, the WinDriver interrupt handling APIs also support Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X), as detailed in Section 9.2 of the manual.

WinDriver also features enhanced support for PCI Express cards with the Xilinx Bus Master DMA (BMD) design. The relevant files are found in the **WinDriver/xilinx/bmd_design** directory. The sample code includes library APIs, a user-mode diagnostics application, and Kernel PlugIn [11] code for communicating with the card using the WinDriver APIs, including DMA and MSI handling.

Chapter 9
Advanced Issues

This chapter covers advanced driver development issues and contains guidelines for using WinDriver to perform tasks that cannot be fully automated by the DriverWizard.

Note that WinDriver's enhanced support for specific chipsets [7] includes custom APIs for performing hardware-specific tasks like DMA and interrupt handling, thus freeing developers of drivers for these chipsets from the need to implement the code for performing these tasks themselves.

9.1. Performing Direct Memory Access (DMA)

This section describes how to use WinDriver to implement bus-master Direct Memory Access (**DMA**) for devices capable of acting as bus masters. Such devices have a DMA controller, which the driver should program directly.

DMA is a capability provided by some computer bus architectures, including PCI, PCMCIA and CardBus, which allows data to be sent directly from an attached device to the memory on the host, freeing the CPU from involvement with the data transfer and thus improving the host's performance.

A DMA buffer can be allocated in two ways:

- **Contiguous Buffer:** A contiguous block of memory is allocated.
- **Scatter/Gather:** The allocated buffer can be fragmented in the physical memory and does not need to be allocated contiguously. The allocated physical memory blocks are mapped to a contiguous buffer in the calling process's virtual address space, thus enabling easy access to the allocated physical memory blocks.

The programming of a device's DMA controller is hardware specific. Normally, you need to program your device with the *local address* (on your device), the *host address* (the physical memory address on your PC) and the *transfer count* (the size of the memory block to transfer), and then set the register that initiates the transfer.

WinDriver provides you with API for implementing both Contiguous Buffer DMA and Scatter/Gather DMA (if supported by the hardware) – see the description of `WDC_DMAContigBufLock()` [B.3.39], `WDC_DMASGBufLock()` [B.3.40], and `WDC_DMABufUnlock()` [B.3.41]. (The lower-level `WD_DMAxxx` API is described in the **WinDriver PCI Low-Level API Reference**, but we recommend using the convenient wrapper `WDC_xxx` API instead.)

This section includes code samples that demonstrate how to use WinDriver to implement Scatter/Gather and Contiguous Buffer DMA.

- The sample routines demonstrate using either an interrupt mechanism or a polling mechanism to determine DMA completion.
- The sample routines allocate a DMA buffer and enable DMA interrupts (if polling is not used) and then free the buffer and disable the interrupts (if enabled) for each DMA transfer. However, when you implement your actual DMA code, you can allocate DMA buffer(s) once, at the beginning of your application, enable the DMA interrupts (if polling is not used), then perform DMA transfers repeatedly, using the same buffer(s), and disable the interrupts (if enabled) and free the buffer(s) only when your application no longer needs to perform DMA.
- On Mac OS X, if there aren't enough resources to accommodate the DMA buffer allocation request, the process will hang, since the OS waits for the required resources to be available. Take this into consideration when setting up your DMA buffer allocations.

9.1.1. Scatter/Gather DMA

Following is a sample routine that uses WinDriver's WDC API [B.2] to allocate a Scatter/Gather DMA buffer and perform bus-master DMA transfers.

A more detailed example, which is specific to the enhanced support for PLX chipsets [7] can be found in the **WinDriver/plx/lib/plx_lib.c** library file and **WinDriver/plx/diag_lib/plx_diag_lib.c** diagnostics library file (which utilizes the **plx_lib.c** DMA API).
A sample that uses the basic `WD_DMAxxx` API for implementing Scatter/Gather DMA for the Altera PCI dev kit board can be found in the **WinDriver/altera/pci_dev_kit/lib/altera_lib.c** library file.

9.1.1.1. Sample Scatter/Gather DMA Implementation

```
BOOL DMARoutine(WDC_DEVICE_HANDLE hDev, DWORD dwBufSize,
{
    PVOID pBuf;
    WD_DMA *pDma = NULL;
    BOOL fRet = FALSE;

    /* Allocate a user-mode buffer for Scatter/Gather DMA */
    pBuf = malloc(dwBufSize);
    if (!pBuf)
        return FALSE;

    /* Lock the DMA buffer and program the DMA controller */
    if (!DMAOpen(hDev, pBuf, u32LocalAddr, dwBufSize, fToDev, &pDma))
        goto Exit;
```

```
    /* Enable DMA interrupts (if not polling) */
    if (!fPolling)
    {
        if (!MyDMAInterruptEnable(hDev, MyDmaIntHandler, pDma))
            goto Exit; /* Failed enabling DMA interrupts */
    }

    /* Flush the CPU caches (see documentation of WDC_DMASyncCpu()) */
    WDC_DMASyncCpu(pDma);

    /* Start DMA - write to the device to initiate the DMA transfer */
    MyDMAStart(hDev, pDma);

    /* Wait for the DMA transfer to complete */
    MyDMAWaitForCompletion(hDev, pDma, fPolling);

    /* Flush the I/O caches (see documentation of WDC_DMASyncIo()) */
    WDC_DMASyncIo(pDma);

    fRet = TRUE;
Exit:
    DMAClose(pDma, fPolling);
    free(pBuf);
    return fRet;
}

/* DMAOpen: Locks a Scatter/Gather DMA buffer */
BOOL DMAOpen(WDC_DEVICE_HANDLE hDev, PVOID pBuf, UINT32 u32LocalAddr,
    DWORD dwDMABufSize, BOOL fToDev, WD_DMA **ppDma)
{
    DWORD dwStatus, i;
    DWORD dwOptions = fToDev ? DMA_TO_DEVICE : DMA_FROM_DEVICE;

    /* Lock a Scatter/Gather DMA buffer */
    dwStatus = WDC_DMASGBufLock(hDev, pBuf, dwOptions, dwDMABufSize, ppDma);
    if (WD_STATUS_SUCCESS != dwStatus)
    {
        printf("Failed locking a Scatter/Gather DMA buffer. Error 0x%lx - %s\n",
            dwStatus, Stat2Str(dwStatus));
        return FALSE;
    }

    /* Program the device's DMA registers for each physical page */
    MyDMAProgram((*ppDma)->Page, (*ppDma)->dwPages, fToDev);

    return TRUE;
}

/* DMAClose: Unlocks a previously locked Scatter/Gather DMA buffer */
void DMAClose(WD_DMA *pDma, BOOL fPolling)
{
    /* Disable DMA interrupts (if not polling) */
    if (!fPolling)
        MyDMAInterruptDisable(hDev);

    /* Unlock and free the DMA buffer */
    WDC_DMABufUnlock(pDma);
}
```

9.1.1.2. What Should You Implement?

In the code sample above, it is up to you to implement the following `MyDMAxxx`() routines, according to your device's specification

- `MyDMAProgram`(): Program the device's DMA registers.
  Refer the device's data sheet for the details.

- `MyDMAStart`(): Write to the device to initiate DMA transfers.

- `MyDMAInterruptEnable`() and `MyDMAInterruptDisable`(): Use `WDC_IntEnable`() [B.3.46] and `WDC_IntDisable`() [B.3.47] (respectively) to enable/disable the software interrupts and write/read the relevant register(s) on the device in order to physically enable/disable the hardware DMA interrupts (see Section 9.2 for details regarding interrupt handling with WinDriver.)

- `MyDMAWaitForCompletion`(): Poll the device for completion or wait for "DMA DONE" interrupt.

When using the basic `WD_xxx` API (described in the **WinDriver PCI Low-Level API Reference**) to allocate a Scatter/Gather DMA buffer that is larger than 1MB, you need to set the `DMA_LARGE_BUFFER` flag in the call to `WD_DMALock`() and allocate memory for the additional memory pages, as explained in the following FAQ: http://www.jungo.com/st/support/faq.html#dma1. However, when using `WDC_DMASGBufLock`() [B.3.40] to allocate the DMA buffer, you do not need any special implementation for allocating large buffers, since the function handles this for you.
(Note that on Mac OS X, allocation of large buffers may cause the process to hang, if there aren't enough resources to accommodate the request – refer to the Mac OS X note in Section 9.1.)

9.1.2. Contiguous Buffer DMA

Following is a sample routine that uses WinDriver's WDC API [B.2] to allocate a Contiguous DMA buffer and perform bus-master DMA transfers.

A more detailed example specific to the enhanced support PLX chipsets [7] can be found in the **WinDriver/plx/lib/plx_lib.c** library file and **WinDriver/plx/diag_lib/plx_diag_lib.c** diagnostics library file (which utilizes the **plx_lib.c** DMA API.)
A sample of using the basic `WD_DMAxxx` API for implementing Contiguous Buffer DMA for the AMCC 5933 chip can be found in the **WinDriver/amcc/lib/amcclib.c** library file (the `WD_DMAxxx` API is described in the **WinDriver PCI Low-Level API Reference**).

9.1.2.1. Sample Contiguous Buffer DMA Implementation

```
BOOL DMARoutine(WDC_DEVICE_HANDLE hDev, DWORD dwDMABufSize,
    UINT32 u32LocalAddr, DWORD dwOptions, BOOL fPolling, BOOL fToDev)
{
    PVOID pBuf = NULL;
    WD_DMA *pDma = NULL;
    BOOL fRet = FALSE;

    /* Allocate a DMA buffer and open DMA for the selected channel */
    if (!DMAOpen(hDev, &pBuf, u32LocalAddr, dwDMABufSize, fToDev, &pDma))
        goto Exit;

    /* Enable DMA interrupts (if not polling) */
    if (!fPolling)
    {
        if (!MyDMAInterruptEnable(hDev, MyDmaIntHandler, pDma))
            goto Exit; /* Failed enabling DMA interrupts */
    }

    /* Flush the CPU caches (see documentation of WDC_DMASyncCpu()) */
    WDC_DMASyncCpu(pDma);

    /* Start DMA - write to the device to initiate the DMA transfer */
    MyDMAStart(hDev, pDma);

    /* Wait for the DMA transfer to complete */
    MyDMAWaitForCompletion(hDev, pDma, fPolling);

    /* Flush the I/O caches (see documentation of WDC_DMASyncIo()) */
    WDC_DMASyncIo(pDma);

    fRet = TRUE;

Exit:
    DMAClose(pDma, fPolling);
    return fRet;
}

/* DMAOpen: Allocates and locks a Contiguous DMA buffer */
BOOL DMAOpen(WDC_DEVICE_HANDLE hDev, PVOID *ppBuf, UINT32 u32LocalAddr,
    DWORD dwDMABufSize, BOOL fToDev, WD_DMA **ppDma)
{
    DWORD dwStatus;
    DWORD dwOptions = fToDev ? DMA_TO_DEVICE : DMA_FROM_DEVICE;

    /* Allocate and lock a Contiguous DMA buffer */
    dwStatus = WDC_DMAContigBufLock(hDev, ppBuf, dwOptions, dwDMABufSize, ppDma);
    if (WD_STATUS_SUCCESS != dwStatus)
    {
        printf("Failed locking a Contiguous DMA buffer. Error 0x%lx - %s\n",
            dwStatus, Stat2Str(dwStatus));
        return FALSE;
    }

    /* Program the device's DMA registers for the physical DMA page */
    MyDMAProgram((*ppDma)->Page, (*ppDma)->dwPages, fToDev);
```

```
    return TRUE;
}

/* DMAClose: Frees a previously allocated Contiguous DMA buffer */
void DMAClose(WD_DMA *pDma, BOOL fPolling)
{
    /* Disable DMA interrupts (if not polling) */
    if (!fPolling)
        MyDMAInterruptDisable(hDev);

    /* Unlock and free the DMA buffer */
    WDC_DMABufUnlock(pDma);
}
```

9.1.2.2. What Should You Implement?

In the code sample above, it is up to you to implement the following `MyDMAxxx`() routines, according to your device's specification

- `MyDMAProgram`(): Program the device's DMA registers.
  Refer the device's data sheet for the details.

- `MyDMAStart`(): Write to the device to initiate DMA transfers.

- `MyDMAInterruptEnable`() and `MyDMAInterruptDisable`(): Use `WDC_IntEnable`() [B.3.46] and `WDC_IntDisable`() [B.3.47] (respectively) to enable/disable the software interrupts and write/read the relevant register(s) on the device in order to physically enable/disable the hardware DMA interrupts (see Section 9.2 for details regarding interrupt handling with WinDriver.)

- `MyDMAWaitForCompletion`(): Poll the device for completion or wait for "DMA DONE" interrupt.

9.1.3. Performing DMA on SPARC

The SPARC platform supports Direct Virtual Memory Access (**DVMA**). Platforms that support DVMA provide the device with a virtual address rather than a physical address. With this memory access method, the platform translates device accesses to the provided virtual address into the proper physical addresses using a type of Memory Management Unit (MMU). The device transfers data to and from a contiguous virtual image that can be mapped to dis-contiguous physical pages. Devices that operate on these platforms do not require Scatter/Gather DMA capability.

9.2. Handling Interrupts

WinDriver provides you with API, DriverWizard code generation, and samples, to simplify the task of handling interrupts from your driver.

If you are developing a driver for a device based on one of the enhanced-support WinDriver chipsets [7], we recommend that you use the custom WinDriver interrupt APIs for your specific chip in order to handle the interrupts, since these routines are implemented specifically for the target hardware.

For other chips, we recommend that you use DriverWizard to detect/define the relevant information regarding the device interrupt (such as the interrupt request (IRQ) number, its type and its shared state), define commands to be executed in the kernel when an interrupt occurs (if required), and then generate skeletal diagnostics code, which includes interrupt routines that demonstrate how to use WinDriver's API to handle your device's interrupts, based on the information that you defined in the wizard.

The following sections provide a general overview of PCI/PCMCIA/ISA interrupt handling and explain how to handle interrupts using WinDriver's API. Use this information to understand the sample and generated DriverWizard interrupt code or to write your own interrupt handler.

9.2.1. Interrupt Handling – Overview

PCI, PCMIA and ISA hardware uses interrupts to signal the host.
There are two main methods of PCI interrupt handling:

- **Legacy Interrupts:** The traditional interrupt handling, which uses a line-based mechanism. In this method, interrupts are signaled by using one or more external pins that are wired "out-of-band", i.e., separately from the main bus lines.

  Legacy interrupts are divided into two groups:

  - **Level-sensitive interrupts:** These interrupts are generated as long as the physical interrupt signal is high. If the interrupt signal is not lowered by the end of the interrupt handling in the kernel, the operating system will call the kernel interrupt handler repeatedly causing the host platform to hang. To prevent such a situation, the interrupt must be acknowledged (cleared) by the kernel interrupt handler immediately when it is received.

    Legacy PCI interrupts are level sensitive.

  - **Edge-triggered interrupts:** These are interrupts that are generated once, when the physical interrupt signal goes from low to high. Therefore, exactly one interrupt is generated. No special action is required in order to acknowledge this type of interrupt.

    ISA/EISA interrupts are edge triggered.

- **MSI/MSI-X:** Newer PCI bus technologies, available beginning with v2.2 of the PCI bus and in PCI Express, support Message-Signaled Interrupts (**MSI**). This method uses "in-band"

messages instead of pins and can target addresses in the host bridge. A PCI function can request up to 32 MSI messages.
Note: MSI and MSI-X are edge triggered and do not require acknowledgment in the kernel.

Among the advantages of MSIs:

- MSIs can send data along with the interrupt message.
- As opposed to legacy PCI interrupts, MSIs are not shared, i.e., an MSI that is assigned to a device is guaranteed to be unique within the system.

Extended Message-Signaled Interrupts (**MSI-X**) are available beginning with version 3.0 of the PCI bus. This method provides an enhanced version of the MSI mechanism, which includes the following advantages:

- Supports 2,048 messages instead of 32 messages supported by the standard MSI.
- Supports independent message address and message data for each message.
- Supports per-message masking.
- Enables more flexibility when software allocates fewer vectors than hardware requests. The software can reuse the same MSI-X address and data in multiple MSI-X slots.

The newer PCI buses, which support MSI/MSI-X, maintain software compatibility with the legacy line-based interrupts mechanism by emulating legacy interrupts through in-band mechanisms. These emulated interrupts are treated as legacy interrupts by the host operating system.

WinDriver supports legacy line-based interrupts, both edge triggered and level sensitive, on all supported operating systems: Windows, Windows CE, Mac OS X, and Linux. (For Windows CE, see specific information in Section 9.2.8).

WinDriver also supports PCI MSI/MSI-X interrupts (when supported by the hardware) on Linux, Mac OS X, and Windows Vista and higher (earlier versions of Windows do not support MSI/MSI-X), as detailed in Section 9.2.6.

WinDriver provides a single set of APIs for handling both legacy and MSI/MSI-X interrupts, as described in this manual.

9.2.2. WinDriver Interrupt Handling Sequence

This section describes how to use WinDriver to handle interrupts from a user-mode application. Since interrupt handling is a performance-critical task, it is very likely that you may want to handle the interrupts directly in the kernel. WinDriver's Kernel PlugIn [11] enables you to implement kernel-mode interrupt routines.
To find out how to handle interrupts from the Kernel PlugIn, please refer to Section 11.6.5 of the manual.

The interrupt handling sequence using WinDriver is as follows:

1. The user calls one of WinDriver's interrupt enable functions – `WDC_IntEnable`() [B.3.46] or the low-level `InterruptEnable`() or `WD_IntEnable`() functions, described in the **WinDriver PCI Low-Level API Reference** – to enable interrupts on the device.
   These functions receive an optional array of read/write transfer commands to be executed in the kernel when an interrupt occurs (see Step 3).

   NOTE:

   - When using WinDriver to handle level-sensitive interrupts, you **must** set up transfer commands for acknowledging the interrupt, as explained in Section 9.2.5.

   - Memory allocated for the transfer commands must remain available until the interrupts are disabled .

   When `WDC_IntEnable`() [B.3.46] or the lower-level `InterruptEnable`() function is called, WinDriver spawns a thread for handling incoming interrupts.
   When using the low-level `WD_IntEnable`() function you need to spawn the thread yourself.

   WinDriver must be registered with the OS as the driver of the device before enabling interrupts. For Plug-and-Play hardware (PCI/PCI Express/PCMCIA) on Windows platforms, this association is made by installing an INF file for the device [15.1]. If the INF file is not installed, `the interrupt enable function`() will fail with a `WD_NO_DEVICE_OBJECT` error [B.9].

2. The interrupt thread runs an infinite loop that waits for an interrupt to occur.

3. When an interrupt occurs, WinDriver executes, in the kernel, any transfer commands that were prepared in advance by the user and passed to WinDriver's interrupt-enable functions (see Section 9.2.5).
   When the control returns to the user mode, the driver's user-mode interrupt handler routine (as passed to WinDriver when enabling the interrupts with `WDC_IntEnable`() or `InterruptEnable`()) is called.

4. When the user-mode interrupt handler returns, the wait loop continues.

5. When the user no longer needs to handle interrupts, or before the user-mode application exits, the relevant WinDriver interrupt disable function should be called – `WDC_IntDisable`() [B.3.47] or the low-level `InterruptDisable`() or `WD_IntDisable`() functions, described in the **WinDriver PCI Low-Level API Reference** (depending on the function used to enable the interrupts).

© Jungo Ltd. 2005–2011

- The low-level `WD_IntWait()` WinDriver function (described in the **WinDriver PCI Low-Level API Reference**), which is used by the high-level interrupt enable functions to wait on interrupts from the device, puts the thread to sleep until an interrupt occurs. **There is no CPU consumption while waiting for an interrupt.** Once an interrupt occurs, it is first handled by the WinDriver kernel, then `WD_IntWait()` wakes up the interrupt handler thread and returns, as explained above.

- Since your interrupt handler runs in the user mode, you may call any OS API from this function, including file-handling and GDI functions.

9.2.3. Determining the Interrupt Types Supported by the Hardware

When retrieving resources information for a Plug-and-Play device using `WDC_PciGetDeviceInfo()` [B.3.8] (PCI) or `WDC_PcmciaGetDeviceInfo()` [B.3.9] (PCMCIA), or the low-level `WD_PciGetCardInfo()` or `WD_PcmciaGetCardInfo()` function (described in the **WinDriver PCI Low-Level API Reference**), the function returns information regarding the interrupt types supported by the hardware. This information is returned within the **`dwOptions`** field of the returned interrupt resource (`pDeviceInfo->Card.Item[i].I.Int.dwOptions` for the WDC functions `pPciCard->Card.Item[i].I.Int.dwOptions` for the low-level functions). The interrupt options bit-mask can contain a combination of any of the following interrupt type flags:

- **`INTERRUPT_MESSAGE_X`**: Extended Message-Signaled Interrupts (MSI-X).*
- **`INTERRUPT_MESSAGE`**: Message-Signaled Interrupts (MSI).*
- **`INTERRUPT_LEVEL_SENSITIVE`**: Legacy level-sensitive interrupts.
- **`INTERRUPT_LATCHED`**: Legacy edge-triggered interrupts. The value of this flag is zero and it is applicable only when no other interrupt flag is set.

The **`WDC_GET_INT_OPTIONS`** macro returns a WDC device's interrupt options bit-mask [B.4.9]. You can pass the returned bit-mask to the **`WDC_INT_IS_MSI`** macro to check whether the bit-mask contains the MSI or MSI-X flags [B.4.10].

- The **`INTERRUPT_MESSAGE`** and **`INTERRUPT_MESSAGE_X`** flags are applicable only to PCI devices [9.2.6].

- * The Windows and Mac OS X APIs do not distinguish between MSI and MSI-X; therefore, on these OSs the WinDriver functions set the **`INTERRUPT_MESSAGE`** flag for both MSI and MSI-X.

9.2.4. Determining the Interrupt Type Enabled for a PCI Card

When attempting to enable interrupts for a PCI card on Linux, Mac OS X, or Windows Vista and higher, WinDriver first tries to use MSI-X or MSI, if supported by the card. If this fails, WinDriver attempts to enable legacy level-sensitive interrupts.
WinDriver's interrupt enable functions return information regarding the interrupt type that was enabled for the card. This information is returned within the **`dwEnabledIntType`** field of the `WD_INTERRUPT` structure that was passed to the function. When using the high-level `WDC_IntEnable`() function, the information is stored within the `Int` field of the WDC device structure referred to by the function's `hDev` parameter [B.3.46], and can be retrieved using the **`WDC_GET_ENABLED_INT_TYPE`** low-level WDC macro [B.4.8].

9.2.5. Setting Up Kernel-Mode Interrupt Transfer Commands

When handling interrupts you may find the need to perform high-priority tasks at the kernel-mode level immediately when an interrupt occurs. For example, when handling level-sensitive interrupts, such as legacy PCI interrupts [9.2.1], the interrupt line **must** be lowered (i.e., the interrupt must be acknowledged) in the kernel, otherwise the operating system will repeatedly call WinDriver's kernel interrupt handler, causing the host platform to hang. Acknowledgment of the interrupt is hardware-specific and typically involves writing or reading from specific runtime registers on the device. PCMCIA interrupts also require hardware-specific kernel-mode interrupt handling.

WinDriver's interrupt enable functions receive an optional pointer to an array of `WD_TRANSFER` structures [B.5.15], which can be used to set up read/write transfer command from/to memory or I/O addresses on the device.
The `WDC_IntEnable`() function [B.3.46] accepts this pointer and the number of commands in the array as direct parameters (`pTransCmds` and `dwNumCmds`).
The low-level `InterruptEnable`() and `WDC_IntEnable`() functions receive this information within the `Cmd` and `dwCmds` fields of the `WD_INTERRUPT` structure that is passed to them (see the **WinDriver PCI Low-Level API Reference**).

When you need to execute performance-critical transfers to/from your device upon receiving an interrupt – e.g., when handling level-sensitive interrupts – you should prepare an array of `WD_TRANSFER` structures that contain the required information regarding the read/write operations to perform in the kernel upon arrival of an interrupt, and pass this array to WinDriver's interrupt enable functions. As explained in Section 9.2.2, Step 3, WinDriver's kernel-mode interrupt handler will execute the transfer commands passed to it within the interrupt enable function for each interrupt that it handles, before returning the control to the user mode. Note: Memory allocated for the transfer commands must remain available until the interrupts are disabled .

© Jungo Ltd. 2005–2011

9.2.5.1. Interrupt Mask Commands

The interrupt transfer commands array that you pass to WinDriver can also contain an interrupt mask structure, which will be used to verify the source of the interrupt. This is done by setting the transfer structure's `cmdTrans` field, which defines the type of the transfer command, to **`CMD_MASK`**, and setting the relevant mask in the transfer structure's `Data` field [B.5.15]. Note that interrupt mask commands must be set directly after a read transfer command in the transfer commands array.

When WinDriver's kernel interrupt handler encounters a mask interrupt command, it masks the value that was read from the device in the preceding read transfer command in the array, with the mask set in the interrupt mask command. If the mask is successful, WinDriver will claim control of the interrupt, execute the rest of the transfer commands in the array, and invoke your user-mode interrupt handler routine when the control returns to the user mode. However, if the mask fails, WinDriver will reject control of the interrupt, the rest of the interrupt transfer commands will not be executed, and your user-mode interrupt handler routine will not be invoked. (Note: acceptance and rejection of the interrupt is relevant only when handling legacy interrupts; since MSI/MSI-X interrupts are not shared, WinDriver will always accept control of such interrupts.)

- To correctly handle shared PCI interrupts, you must always include a mask command in your interrupt transfer commands array, and set up this mask to check whether the interrupt handler should claim ownership of the interrupt.

- On **Windows CE**, in the case of a shared interrupt, WinDriver's interrupt handler will execute the first mask command that is found in the provided interrupt transfer commands array, together with the related read command that precedes it (see information above), before executing any other commands in the array, *including commands that precede the mask command*.

  Ownership of the interrupt will be determined according to the result of this mask. If the mask fails, no other transfer commands from the transfer commands array will be executed – including commands that preceded the mask command in the array. If the mask succeeds, WinDriver will proceed to perform any commands that precede the first mask command (and its related read command) in the transfer commands array, and then any commands that follow the mask command in the array.

- To gain more flexibility and control over the interrupt handling, you can use WinDriver's Kernel PlugIn feature, which enables you to write your own kernel-mode interrupt handler routines, as explained in Section 11.6.5 of the manual. Note that Kernel PlugIn is not implemented under Windows CE [11].

9.2.5.2. Sample WinDriver Transfer Commands Code

This section provides sample code for setting up interrupt transfer commands using the WinDriver Card (WDC) library API [B.2].
The sample code is provided for the following scenario: Assume you have a PCI card that generates level-sensitive interrupts. When an interrupt occurs you expect the value of your card's

interrupt command-status register (`INTCSR`), which is mapped to an I/O port address (`dwAddr`), to be `intrMask`.
In order to clear and acknowledge the interrupt you need to write 0 to the `INTCSR`.

The code below demonstrates how to define an array of transfer commands that instructs WinDriver's kernel-mode interrupt handler to do the following:

1. Read your card's `INTCSR` register and save its value.

2. Mask the read `INTCSR` value against the given mask (`intrMask`) to verify the source of the interrupt.

3. If the mask was successful, write 0 to the `INTCSR` to acknowledge the interrupt.

Note: all commands in the example are performed in modes of DWORD.

EXAMPLE

```
WD_TRANSFER trans[3]; /* Array of 3 WinDriver transfer command structures */
BZERO(trans);

/* 1st command: Read a DWORD from the INTCSR I/O port */
trans[0].cmdTrans = RP_DWORD;
/* Set address of IO port to read from: */
trans[0].dwPort = dwAddr; /* Assume dwAddr holds the address of the INTCSR */

/* 2nd command: Mask the interrupt to verify its source */
trans[1].cmdTrans = CMD_MASK;
trans[1].Data.Dword = intrMask; /* Assume intrMask holds your interrupt mask */

/* 3rd command: Write DWORD to the INTCSR I/O port.
   This command will only be executed if the value read from INTCSR in the
   1st command matches the interrupt mask set in the 2nd command. */
trans[2].cmdTrans = WP_DWORD;
/* Set the address of IO port to write to: */
trans[2].dwPort = dwAddr; /* Assume dwAddr holds the address of INTCSR */
/* Set the data to write to the INTCSR IO port: */
trans[2].Data.Dword = 0;
```

After defining the transfer commands, you can proceed to enable the interrupts.
Note that memory allocated for the transfer commands must remain available until the interrupts are disabled , as explained above.
The following code demonstrates how to use the `WDC_IntEnable`() function to enable the interrupts using the transfer commands prepared above:

```
/* Enable the interrupts:
   hDev: WDC_DEVICE_HANDLE received from a previous call to WDC_PciDeviceOpen().
   INTERRUPT_CMD_COPY: Used to save the read data - see WDC_IntEnable().
   interrupt_handler: Your user-mode interrupt handler routine.
   pData: The data to pass to the interrupt handler routine. */
WDC_IntEnable(hDev, &trans, 3, INTERRUPT_CMD_COPY, interrupt_handler,
    pData, FALSE);
```

© Jungo Ltd. 2005–2011

9.2.6. WinDriver MSI/MSI-X Interrupt Handling

As indicated in Section 9.2.1, WinDriver supports PCI Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) on Linux, Mac OS X, and Windows Vista and higher (earlier versions of Windows do not support MSI/MSI-X).
The same APIs are used for handling both legacy and MSI/MSI-X interrupts, and these APIs return information regarding interrupt types supported by your hardware [9.2.3] and the interrupt type that was enabled for it [9.2.4].

WinDriver's kernel-mode interrupt handler sets the interrupt message data in the **`dwLastMessage`** field of the `WD_INTERRUPT` structure that was passed to the interrupt enable/wait function. If you pass the same interrupt structure as part of the data to your user-mode interrupt handler routine, as demonstrated in the sample and generated DriverWizard interrupt code, you will be able to access this information from your interrupt handler.
When using a Kernel PlugIn driver [11], the last message data is passed to your kernel-mode `KP_IntAtDpcMSI` [B.6.11] handler; on Windows Vista and higher, it is also passed to `KP_IntAtIrqlMSI` [B.6.10].
You can use the low-level **`WDC_GET_ENABLED_INT_LAST_MSG`** macro to retrieve the last message data for a given WDC device [B.4.11].

9.2.6.1. Windows MSI/MSI-X Device INF Files

The information in this section is relevant only when working on Windows.

To successfully handle PCI interrupts with WinDriver on Windows, you must first install an INF file that registers your PCI card to work with WinDriver's kernel driver, as explained in Section 15.1.

To use MSI/MSI-X on Windows, the card's INF file must contain specific `[Install.NT.HW]` MSI information, as demonstrated below:

```
[Install.NT.HW]
AddReg = Install.NT.HW.AddReg

[Install.NT.HW.AddReg]
HKR, "Interrupt Management", 0x00000010
HKR, "Interrupt Management\MessageSignaledInterruptProperties", 0x00000010
HKR, "Interrupt Management\MessageSignaledInterruptProperties", MSISupported, \
    0x10001, 1
```

Therefore, to use MSI/MSI-X on Windows Vista and higher with WinDriver – provided your hardware supports MSI/MSI-X – you need to install an appropriate INF file.

When using DriverWizard on Windows Vista and higher to generate an INF file for a PCI device that supports MSI/MSI-X, the INF generation dialogue allows you to select to generate an INF file that supports MSI/MSI-X (see Section 4.2, Step 3).

In addition, the WinDriver sample code for the Xilinx Bus Master DMA (BMD) design, which demonstrates MSI handling, includes a sample MSI INF file for this design – **WinDriver/xilinx/bmd_design/xilinx_bmd.inf**.

© Jungo Ltd. 2005–2011

If your card's INF file does not include MSI/MSI-X information, as detailed above, WinDriver will attempt to handle your card's interrupts using the legacy level-sensitive interrupt handling method, even if your hardware supports MSI/MSI-X.

9.2.7. Sample User-Mode WinDriver Interrupt Handling Code

The sample code below demonstrates how you can use the WDC library's [B.2] interrupt APIs (described in Sections B.3.46–B.3.48 of the manual) to implement a simple user-mode interrupt handler.
For complete interrupt handler source code that uses the WDC interrupt functions, refer, for example, to the WinDriver **pci_diag** (**WinDriver/samples/pci_diag**), **pcmcia_diag** (**WinDriver/samples/pcmcia_diag**), and PLX (**WinDriver/plx**) samples, and to the generated DriverWizard PCI/PCMCIA/ISA code. For a sample of MSI interrupt handling, using the same APIs, refer to the Xilinx Bus Master DMA (BMD) design sample (**WinDriver/xilinx/bmd_design**), or to the code generated by DriverWizard for PCI hardware that supports MSI/MSI-X on the supported operating systems (Linux, Mac OS X, or Windows Vista and higher).

- The following sample code demonstrates interrupt handling for an edge-triggered ISA card. The code does not set up any kernel-mode interrupt transfer commands [9.2.5], which is acceptable in the case of edge-triggered or MSI/MSI-X interrupts [9.2.1]. Note that when using WinDriver to handle level-sensitive or PCMCIA interrupts from the user mode, you must set up transfer commands for acknowledging the interrupt in the kernel, as explained above and as demonstrated in Section 9.2.5.

- As mentioned above [9.2.6], WinDriver provides a single set of APIs for handling both legacy and MSI/MSI-X interrupts. You can therefore also use the following code to handle MSI/MSI-X PCI interrupts (if supported by your hardware), on Linux, Mac OS X, or Windows Vista and higher, by simply replacing the use of `WDC_IsaDeviceOpen`() in the sample with `WDC_PciDeviceOpen`() [B.3.10].

```
VOID DLLCALLCONV interrupt_handler (PVOID pData)
{
    PWDC_DEVICE pDev = (PWDC_DEVICE)pData;

    /* Implement your interrupt handler routine here */

    printf("Got interrupt %d\n", pDev->Int.dwCounter);
}

...

int main()
{
    DWORD dwStatus;
    WDC_DEVICE_HANDLE hDev;
    ...
    WDC_DriverOpen(WDC_DRV_OPEN_DEFAULT, NULL);
    ...
```

```
    hDev = WDC_IsaDeviceOpen(...);
    ...
    /* Enable interrupts. This sample passes the WDC device handle as the data
        for the interrupt handler routine */
    dwStatus = WDC_IntEnable(hDev, NULL, 0, 0,
        interrupt_handler, (PVOID)hDev, FALSE);
    /* WDC_IntEnable() allocates and initializes the required WD_INTERRUPT
        structure, stores it in the WDC_DEVICE structure, then calls
        InterruptEnable(), which calls WD_IntEnable() and creates an interrupt
        handler thread. */
    if (WD_STATUS_SUCCESS != dwStatus)
    {
       printf ("Failed enabling interrupt. Error: 0x%x - %s\n",
           dwStatus, Stat2Str(dwStatus));
    }
    else
    {
        printf("Press Enter to uninstall interrupt\n");
        fgets(line, sizeof(line), stdin);

        WDC_IntDisable(hDev);
        /* WDC_IntDisable() calls InterruptDisable();
           InterruptDisable() calls WD_IntDisable(). */
    }
    ...
    WDC_IsaDeviceClose(hDev);
    ...
    WDC_DriverClose();
}
```

9.2.8. Interrupts on Windows CE

Windows CE uses a logical interrupt scheme rather than the physical interrupt number. It maintains an internal kernel table that maps the physical IRQ number to the logical IRQ number. Device drivers are expected to use the logical interrupt number when requesting interrupts from Windows CE. In this context, there are three approaches to interrupt mapping:

1. **Use Windows CE Plug-and-Play for Interrupt Mapping (PCI bus driver)**
   This is the recommended approach to interrupt mapping on Windows CE. Register the device with the PCI bus driver. Following this method will cause the PCI bus driver to perform the IRQ mapping and direct WinDriver to use it.

   For an example how to register your device with the PCI bus driver, refer to Section 5.3.

2. **Use the Platform Interrupt Mapping** (On x86 or ARM)
   In most of the x86 or MIPS platforms, all physical interrupts, except for a few reserved interrupts, are statically mapped using this simple mapping:
   `logical interrupt = SYSINTR_FIRMWARE + physical interrupt`

   When the device is not registered with Windows CE Plug-and-Play, WinDriver will follow this mapping.

3. **Specify the Mapped Interrupt Value**

This option can only be performed by the Platform Builder.

Provide the device's mapped logical interrupt value. If unavailable, statically map the physical IRQ to a logical interrupt. Then call `WD_CardRegister()` with the logical interrupt and with the **`INTERRUPT_CE_INT_ID`** flag set. The static interrupt map is in the file **CFWPC.C** (located in the **%_TARGETPLATROOT%\KERNEL\HAL** directory).

You will then need to rebuild the Windows CE image **NK.BIN** and download the new executable onto your target platform.

Static mapping is helpful also in the case of using reserved interrupt mapping. Suppose your platform static mapping is:

- **IRQ0**: Timer Interrupt
- **IRQ2**: Cascade interrupt for the second PIC
- **IRQ6**: The floppy controller
- **IRQ7**: LPT1 (because the PPSH does not use interrupts)
- **IRQ9**
- **IRQ13**: The numeric coprocessor

An attempt to initialize and use any of these interrupts will fail. However, you may want to use one or more of these interrupts on occasion, such as when you do not want to use the PPSH, but you want to reclaim the parallel port for some other purpose. To solve this problem, simply modify the file **CFWPC.C** (located in the **%_TARGETPLATROOT%\KERNEL\HAL** directory) to include code, as shown below, that sets up a value for interrupt 7 in the interrupt mapping table:

```
SETUP_INTERRUPT_MAP(SYSINTR_FIRMWARE+7,7);
```

Suppose you have a PCI card which was assigned IRQ9. Since Windows CE does not map this interrupt by default, you will not be able to receive interrupts from this card. In this case, you will need to insert a similar entry for IRQ9:

```
SETUP_INTERRUPT_MAP(SYSINTR_FIRMWARE+9,9);
```

9.2.8.1. Improving Interrupt Latency on Windows CE

You can reduce the interrupt latency on Windows CE for PCI devices by making slight changes in the registry and in your code:

1. When developing your driver on Windows CE platforms, you must first register your device to work with WinDriver, as explained in Section 5.3.
   Change the last value in the registry from

```
"WdIntEnh"=dword:0
```
to
```
"WdIntEnh"=dword:1
```

If you exclude this line, or leave the value 0, the interrupt latency will not be reduced.

2. Add **WD_CE_ENHANCED_INTR** to your Preprocessor Definitions of your project and recompile your entire project. When using Microsoft eMbedded Visual C++, the Preprocessor Definitions are found under Project Settings.

3. When using the low-level `WD_xxx` API (described in the **WinDriver PCI Low-Level API Reference**), call **`WD_InterruptDoneCe()`** immediately after calling `WD_IntEnable`().

When using WinDriver's **WDC APIs** [B.2] to handle the interrupts, or when enabling interrupts using the lower-level `InterruptEnable`() function (described in the **WinDriver PCI Low-Level API Reference**), you do not need to call `WD_InterruptDoneCe`(), since `WDC_IntEnable`() [B.3.46] / `InterruptEnable`() automatically call `WD_InterruptDoneCe`().

`WD_InterruptDoneCe`() receives two parameters:

```
void WD_InterruptDoneCe(HANDLE hWD, WD_INTERRUPT pInt);
```

- **`hWD`**: Handle to WinDriver's kernel-mode driver as received from `WD_Open`() (see description of `WD_Open`() in the **WinDriver PCI Low-Level API Reference**)

- **`pInt`**: Pointer to a `WD_INTERRUPT` structure returned from `WD_IntEnable`()

9.3. Byte Ordering

9.3.1. Introduction to Endianness

There are two main architectures for handling memory storage. They are called Big Endian and Little Endian and refer to the order in which the bytes are stored in memory.

- Big endian means that the most significant byte of any multi-byte data field is stored at the lowest memory address.
  This means a Hex word like 0x1234 is stored in memory as (0x12 0x34). The big end, or upper end, is stored first. The same is true for a four-byte value; for example, 0x12345678 would be stored as (0x12 0x34 0x56 0x78).

- Little endian means that the least significant byte of any multi-byte data field is stored at the lowest memory address.
  This means a Hex word like 0x1234 is stored in memory as (0x34 0x12). The little end, or lower end, is stored first. The same is true for a four-byte value; for example, 0x12345678 would be stored as (0x78 0x56 0x34 0x12).

© Jungo Ltd. 2005–2011

All processors are designated as either big endian or little endian. Intel's x86 processors and their clones are little endian. Sun's SPARC, Motorola's 68K, and the PowerPC families are all big endian.

An endianness difference can cause problems if a computer unknowingly tries to read binary data written in the opposite format from a shared memory location or file.

The terms big endian and little endian are derived from the Lilliputians of Gulliver's Travels (Jonathan Swift 1726), whose major political issue was which end of the soft-boiled egg should be opened, the little or the big end.

9.3.2. WinDriver Byte Ordering Macros

The PCI bus is designated as little endian, complying with x86 architecture. In order to prevent problems resulting from byte ordering incompatibility between the PCI bus and SPARC and PowerPC architectures, WinDriver includes macro definitions that convert data between little and big endian.

When developing drivers using WinDriver, these macro definitions enable cross platform portability. Using these macro definitions is safe even for drivers that are going to be deployed on x86 architecture.

The following sections describe the macros and when to use them.

9.3.3. Macros for PCI Target Access

WinDriver's macros for PCI target access are used for converting endianness while reading/ writing from/to PCI cards using memory mapped ranges of PCI devices.

These macro definitions apply to Linux PowerPC architecture.

- **dtoh16** – Macro definition for converting a WORD (device to host)
- **dtoh32** – Macro definition for converting a DWORD (device to host)
- **dtoh64** – Macro definition for converting a QWORD (device to host)

Use these macros in the following situations:

1. To prepare data to be written to the device, in cases of direct write access to the card using a memory mapped range.

   For example:

   ```
   DWORD data = VALUE;
     *mapped_address = dtoh32(data);
   ```

2. To process data that has been read from the device, in cases of direct read access from the card using a memory mapped range.

© Jungo Ltd. 2005–2011

For example:

```
WORD data = dtoh16(*mapped_address);
```

WinDriver's APIs – `WDC_Read/WriteXXX()` [B.3.19–B.3.24], `WDC_MultiTransfer()` [B.3.25], and the lower level `WD_Transfer()` and `WD_MultiTransfer()` functions (see the **WinDriver PCI Low-Level API Reference**) already perform the required byte ordering translations, therefore when using these APIs to read/write memory addresses you do not need to use the `dtoh16/32/64()` macros to convert the data (nor is this required for I/O addresses).

9.3.4. Macros for PCI Master Access

WinDriver's macros for PCI master access are used for converting endianness of data in host memory that is accessed by the PCI master device, i.e., in cases of access that is initiated by the device rather than the host.

These macro definitions apply to both Linux PowerPC and SPARC architectures.

- **htod16** – Macro definition for converting a WORD (host to device)
- **htod32** – Macro definition for converting a DWORD (host to device)
- **htod64** – Macro definition for converting a QWORD (host to device)

Use these macros to prepare data on the host memory to be a read/written by the card. An example of such a case is a chain of descriptors for scatter/gather DMA.

The following example is an extract from the `PLX_DMAOpen()` function in WinDriver's PLX library (see **WinDriver/plx/lib/plx_lib.c**):

```
        /* Setting chain of DMA pages in the memory */
        for (dwPageNumber = 0, u32MemoryCopied = 0;
            dwPageNumber < pPLXDma->pDma->dwPages;
            dwPageNumber++)
        {
            pList[dwPageNumber].u32PADR =
                htod32((UINT32)pPLXDma->pDma->Page[dwPageNumber].pPhysicalAddr);
            pList[dwPageNumber].u32LADR =
                htod32((u32LocalAddr + (fAutoinc ? u32MemoryCopied : 0)));
            pList[dwPageNumber].u32SIZ =
                htod32((UINT32)pPLXDma->pDma->Page[dwPageNumber].dwBytes);
            pList[dwPageNumber].u32DPR =
                htod32((u32StartOfChain + sizeof(DMA_LIST) * (dwPageNumber + 1))
                | BIT0 | (fIsRead ? BIT3 : 0));
            u32MemoryCopied += pPLXDma->pDma->Page[dwPageNumber].dwBytes;
        }

        pList[dwPageNumber - 1].u32DPR |= htod32(BIT1); /* Mark end of chain */
```

Chapter 10
Improving Performance

10.1. Overview

Once your user-mode driver has been written and debugged, you might find that certain modules in your code do not operate fast enough (for example: an interrupt handler or accessing I/O-mapped regions). If this is the case, try to improve performance in one of the following ways:

- Improve the performance of your user-mode driver [10.2].
- Create a Kernel PlugIn driver [11] and move the performance-critical portions of your code to the Kernel PlugIn.

Kernel PlugIn is not implemented under Windows CE. In this operating system there is no separation between kernel mode and user mode, therefore top performance can be achieved without using the Kernel PlugIn. To improve the interrupt handling rate on Windows CE, follow the instructions in Section 9.2.8.1 of the manual.

Use the following checklist to determine how to best improve the performance of your driver.

10.1.1. Performance Improvement Checklist

The following checklist will help you determine how to improve the performance of your driver:

Problem	Solution
ISA Card – accessing an I/O-mapped range on the card	When transferring a large amount of data, use block (string) transfers and/or group several data transfer function calls into a single multi-transfer function call, as explained in Section 10.2.2 below. If this does not solve the problem, handle the I/O at kernel mode by writing a Kernel PlugIn driver, as explained in Chapters 11 and 12 of the manual.
PCI Card – accessing an I/O-mapped range on the card	Avoid using I/O ranges in your hardware design. Use Memory mapped ranges instead as they are accessed significantly faster.

Problem	Solution
Accessing a memory-mapped range on the card	Try to access memory directly instead of using function calls, as explained in Section 10.2.1 below. When transferring large amounts of data, consider also the solution to problem #1 above. If the problem persists, then there is a hardware design problem. You will not be able to increase performance by using any software design method, writing a Kernel PlugIn, or even by writing a full kernel driver.
Interrupt latency – missing interrupts, receiving interrupts too late	Handle the interrupts in the kernel mode by writing a Kernel PlugIn driver, as explained in Chapters 11 and 12.
PCI target access vs. master access	PCI target access is usually slower than PCI master access (bus-master DMA). For large data transfers, bus-master DMA access is preferable. Section 9.1 of the manual explains how to use WinDriver to implement bus-master DMA.

10.2. Improving the Performance of a User-Mode Driver

As a general rule, transfers to memory-mapped regions are faster than transfers to I/O-mapped regions, because WinDriver enables you to access memory-mapped regions directly from the user mode, without the need for a function call, as explained in Section 10.2.1.

In addition, the WinDriver APIs enable you to improve the performance of your I/O and memory data transfers by using block (string) transfers and by grouping several data transfers into a single function call, as explained in Section 10.2.2.

10.2.1. Using Direct Access to Memory-Mapped Regions

When registering a PCI/PCMCIA/ISA card, using `WDC_xxxDeviceOpen`() (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) or the low-level `WD_CardRegister`() function (see the **WinDriver PCI Low-Level API Reference**), WinDriver returns both user-mode and kernel-mode mappings of the card's physical memory regions. These addresses can then be used to access the memory regions on the card directly, either from the user mode or from the kernel mode (respectively), thus eliminating the context switches between the user and kernel modes and the function calls overhead for accessing the memory.

© Jungo Ltd. 2005–2011

The WDC_MEM_DIRECT_ADDR macro [B.4.5] provides the relevant direct memory access base address – user-mode mapping when called from the user-mode / kernel-mode mapping when called from a Kernel PlugIn driver [11] – for a given memory address region on the card. You can then pass the mapped base address to the WDC_ReadMem8/16/32/64 [B.3.19] and WDC_WriteMem8/16/32/64 [B.3.20] macros, along with the desired offset within the selected memory region, to directly access a specific memory address on the card, either from the user mode or in the kernel.
In addition, all the WDC_ReadAddrXXX() [B.3.21] and WDC_WriteAddrXXX() [B.3.22] functions – with the exception of WDC_ReadAddrBlock() [B.3.23] and WDC_WriteAddrBlock() [B.3.24] – access memory addresses directly, using the correct mapping, based on the calling context (user mode/kernel mode).

When using the low-level WD_xxx() APIs, described in the **WinDriver PCI Low-Level API Reference**, the user-mode and kernel-mode mappings of the card's physical memory regions are returned by WD_CardRegister() within the dwTransAddr and dwUserDirectAddr fields of the pCardReg->Card.Item[i] card resource item structures. The dwTransAddr result should be used as a base address in calls to WD_Transfer()or WD_MultiTransfer() or when accessing memory directly from a Kernel PlugIn driver [11]. To access the memory directly from your user-mode process, use dwUserDirectAddr as a regular pointer.

Whatever the method you select to access the memory on your card, it is important to align the base address according to the size of the data type, especially when issuing string transfer commands. Otherwise, the transfers are split into smaller portions.
The easiest way to align data is to use basic types when defining a buffer, i.e.:

```
BYTE buf[len];      /* for BYTE transfers - not aligned */
WORD buf[len];      /* for WORD transfers - aligned on a 2-byte boundary */
UINT32 buf[len];    /* for DWORD transfers - aligned on a 4-byte boundary */
UINT64 buf[len];    /* for QWORD transfers - aligned on a 8-byte boundary */
```

10.2.2. Block Transfers and Grouping Multiple Transfers

To transfer large amounts of data to/from memory addresses or I/O addresses (which by definition cannot be accessed directly, as opposed to memory addresses – see Section 10.2.1), use the following methods to improve performance by reducing the function calls overhead and context switches between the user and kernel modes:

- Perform block (string) transfers using WDC_ReadAddrBlock() [B.3.23] / WDC_WriteAddrBlock() [B.3.24], or the low-level WD_Transfer() function (see **WinDriver PCI Low-Level API Reference**).

- Group several transfers into a single function call, using WDC_MultiTransfer() [B.3.25] or the low-level WD_MultiTransfer() function (see the **WinDriver PCI Low-Level API Reference**).

© Jungo Ltd. 2005–2011

10.2.3. Performing 64-Bit Data Transfers

The ability to perform actual 64-bit transfers is dependent on the existence of support for such transfers by the hardware, CPU, bridge, etc., and can be affected by any of these factors or their specific combination.

WinDriver supports 64-bit PCI data transfers on the supported Windows and Linux 64-bit platforms (see Appendix A for a full list), as well as on Windows and Linux 32-bit x86 platforms.

If your PCI hardware (card and bus) is 64-bit, the ability to perform 64-bit data transfers on 32-bit platforms will enable you to utilize your hardware's broader bandwidth, even if your host operating system is only 32-bit.

This innovative technology makes possible data transfer rates previously unattainable on 32-bit platforms. Drivers developed using WinDriver will attain significantly better performance results than drivers written with the WDK or other driver development tools. To date, such tools do not enable 64-bit data transfer on x86 platforms running 32-bit operating systems. Jungo's benchmark performance testing results for 64-bit data transfer indicate a significant improvement of data transfer rates compared to 32-bit data transfer, guaranteeing that drivers developed with WinDriver will achieve far better performance than 32-bit data transfer normally allows.

You can perform 64-bit data transfers using any of the following methods:

- Call `WDC_ReadAddr64()` [B.3.21] or `WDC_WriteAddr64()` [B.3.22].
- Call `WDC_ReadAddrBlock()` [B.3.23] or `WDC_WriteAddrBlock()` [B.3.24] with an access mode of `WDC_SIZE_64` [B.3.1.4].
- Call `WDC_MultiTransfer()` [B.3.25] or the low-level `WD_Transfer()` or `WD_MultiTransfer()` functions (see **WinDriver PCI Low-Level API Reference**) with QWORD read/write transfer commands (see the documentation of these functions for details).

You can also perform 64-bit transfers to/from the PCI configuration space using `WDC_PciReadCfg64()` [B.3.33] / `WDC_PciWriteCfg64()` [B.3.34] and `WDC_PciReadCfgBySlot64()` [B.3.31] / `WDC_PciWriteCfgBySlot64()` [B.3.32].

© Jungo Ltd. 2005–2011

Chapter 11
Understanding the Kernel PlugIn

This chapter provides a description of WinDriver's Kernel PlugIn feature.

Kernel PlugIn is not implemented under Windows CE. In this operating system there is no separation between kernel mode and user mode, therefore top performance can be achieved without using the Kernel PlugIn. To improve the interrupt handling rate on Windows CE, follow the instructions in Section 9.2.8.1 of the manual.

11.1. Background

The creation of drivers in user mode imposes a fair amount of function call overhead from the kernel to user mode, which may cause performance to drop to an unacceptable level. In such cases, the Kernel PlugIn feature allows critical sections of the driver code to be moved to the kernel while keeping most of the code intact. Using WinDriver's Kernel PlugIn feature, your driver will operate without any degradation in performance.

The advantages of writing a Kernel PlugIn driver over a standard OS kernel-mode driver are:

- All the driver code is written and debugged in user mode.
- The code segments that are moved to kernel mode remain essentially the same and therefore typically no kernel debugging is needed.
- The parts of the code that will run in the kernel through the Kernel PlugIn are platform independent and therefore will run on every platform supported by WinDriver and the Kernel PlugIn. A standard kernel-mode driver will run only on the platform it was written for.

Using WinDriver's Kernel PlugIn feature, your driver will operate without any performance degradation.

11.2. Do I Need to Write a Kernel PlugIn Driver?

Not every performance problem requires you to write a Kernel PlugIn driver. Some performance problems can be solved in the user-mode driver by better utilization of the features that WinDriver provides. For further information, please refer to Chapter 10.

11.3. What Kind of Performance Can I Expect?

Since you can write your own interrupt handler in the kernel with the WinDriver Kernel PlugIn, you can expect to handle about 100,000 interrupts per second without missing any one of them.

11.4. Overview of the Development Process

Using the WinDriver Kernel PlugIn, you normally first develop and debugs the driver in the user mode, using with the standard WinDriver tools. After identifying the performance-critical parts of the code (such as the interrupt handling or access to I/O-mapped memory ranges), you can create a Kernel PlugIn driver, which runs in kernel mode, and drop the performance-critical portions of your code into the Kernel PlugIn driver, thus eliminating the calling overhead and context switches that occur when implementing the same tasks in the user mode.

This unique architecture allows the developer to start with quick and easy development in the user mode, and progress to performance-oriented code only where needed, thus saving development time and providing for virtually zero performance degradation.

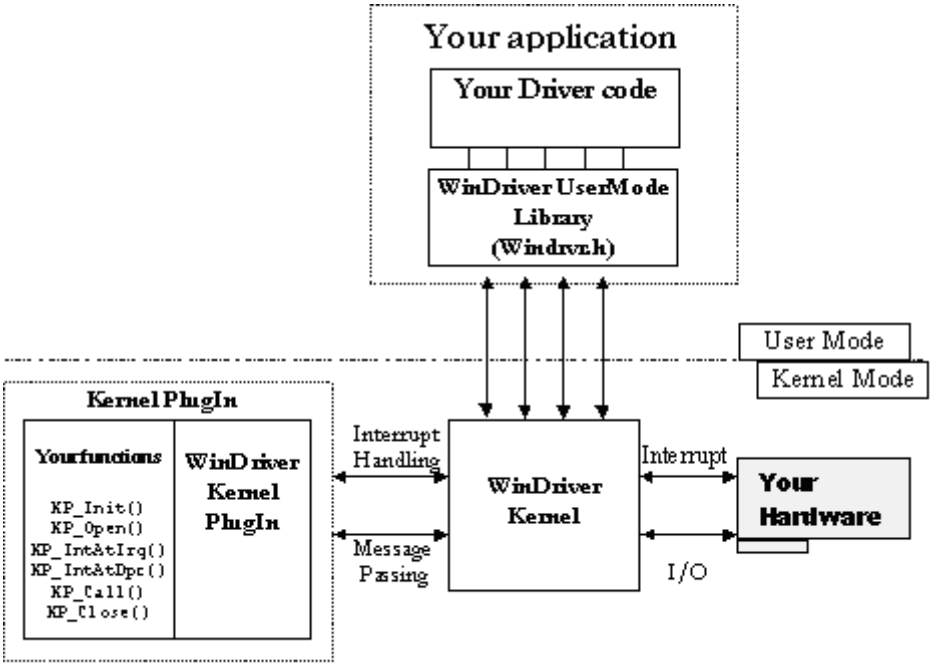
11.5. The Kernel PlugIn Architecture

11.5.1. Architecture Overview

A driver written in user mode uses WinDriver's API (`WDC_xxx` and/or `WD_xxx` [B.2]) to access devices. If a certain function that was implemented in the user mode requires kernel performance (the interrupt handler, for example), that function is moved to the WinDriver Kernel PlugIn. Generally it should be possible to move code that uses `WDC_xxx / WD_xxx` function calls from the user mode to the kernel without modification, since the same WinDriver API is supported both in the user mode and in the Kernel PlugIn.

© Jungo Ltd. 2005–2011

Figure 11.1. Kernel PlugIn Architecture



11.5.2. WinDriver's Kernel and Kernel PlugIn Interaction

There are two types of interaction between the WinDriver kernel and the WinDriver Kernel PlugIn:

- **Interrupt handling:** When WinDriver receives an interrupt, by default it will activate the caller's user-mode interrupt handler. However, if the interrupt was set to be handled by a Kernel PlugIn driver, then once WinDriver receives the interrupt, it activates the Kernel PlugIn driver's kernel-mode interrupt handler. Your Kernel PlugIn interrupt handler could essentially consist of the same code that you wrote and debugged in the user-mode interrupt handler, before moving to the Kernel PlugIn, although some of the user-mode code should be modified. We recommend that you rewrite the interrupt acknowledgment and handling code in the Kernel PlugIn to utilize the flexibility offered by the Kernel PlugIn (see Section 11.6.5).

- **Message passing:** To execute functions in kernel mode (such as I/O processing functions), the user-mode driver simply passes a message to the WinDriver Kernel PlugIn. The message is mapped to a specific function, which is then executed in the kernel. This function can typically contain the same code as it did when it was written and debugged in user mode.
  You can also use messages to pass data from the user-mode application to the Kernel PlugIn driver.

© Jungo Ltd. 2005–2011

11.5.3. Kernel PlugIn Components

At the end of your Kernel PlugIn development cycle, your driver will have the following components:

- User-mode driver application (**<application name>/.exe**), written with the `WDC_xxx / WD_xxx` API.
- The WinDriver kernel module – **windrvr6.sys/.o/.ko** or **WinDriver.kext** – depending on the operating system.
- Kernel PlugIn driver (**<Kernel PlugIn driver name>/.sys/.o/.ko/.kext**), which was also written with the `WDC_xxx / WD_xxx` API, and contains the driver functionality that you have selected to bring down to the kernel level.

11.5.4. Kernel PlugIn Event Sequence

The following is a typical event sequence that covers all the functions that you can implement in your Kernel PlugIn:

11.5.4.1. Opening a Handle from the User Mode to a Kernel PlugIn Driver

Event/Callback	Notes
Event: Windows loads your Kernel PlugIn driver.	This takes place at boot time, by dynamic loading, or as instructed by the registry.
Callback: Your `KP_Init` Kernel PlugIn routine [B.6.1] is called	`KP_Init` informs WinDriver of the name(s) of your `KP_Open` routine(s) [B.6.2]. WinDriver calls the relevant open routine when there is a user-mode request to open a handle to your Kernel PlugIn driver.
Event: Your user-mode driver application requests a handle to your Kernel PlugIn driver, by calling one of the following functions: • `WDC_KernelPlugInOpen`() [B.3.17] • `WDC_xxxDeviceOpen`() (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) with the name of the Kernel PlugIn driver • `WD_KernelPlugInOpen`() – when using the low-level WinDriver API (see the **WinDriver PCI Low-Level API Reference**)	

Event/Callback	Notes
Callback: The relevant `KP_Open` Kernel PlugIn callback routine [B.6.2] is called.	The `KP_Open` [B.6.2] callback is used to inform WinDriver of the names of all the callback functions that you have implemented in your Kernel PlugIn driver, and to initiate the Kernel PlugIn driver, if needed.

11.5.4.2. Handling User-Mode Requests from the Kernel PlugIn

Event/Callback	Notes
Event: Your application calls `WDC_CallKerPlug`() [B.3.18], or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**).	Your application calls `WDC_CallKerPlug`() / `WD_KernelPlugInCall`() to execute code in the kernel mode (in the Kernel PlugIn driver). The application passes a message to the Kernel PlugIn driver. The Kernel PlugIn driver will select the code to execute according to the message sent.
Callback: Your `KP_Call` Kernel PlugIn routine [B.6.4] is called.	`KP_Call` [B.6.4] executes code according to the message passed to it from the user mode.

11.5.4.3. Interrupt Handling – Enable/Disable and High Interrupt Request Level Processing

Event/Callback	Notes
Event: Your application calls `WDC_IntEnable`() [B.3.46] with the `fUseKP` parameter set to `TRUE` (after having opened a handle to the Kernel PlugIn), or calls the low-level `InterruptEnable`() or `WD_IntEnable`() functions (see the **WinDriver PCI Low-Level API Reference**) with a handle to a Kernel PlugIn driver (set in the `hKernelPlugIn` field of the `WD_INTERRUPT` structure passed to the function).	
Callback: Your `KP_IntEnable` Kernel PlugIn routine [B.6.6] is called.	This function should contain any initialization required for your Kernel PlugIn interrupt handling.
Event: Your hardware creates an interrupt.	

Event/Callback	Notes
Callback: Your high-IRQL Kernel PlugIn interrupt handler routine – `KP_IntAtIrql` [B.6.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.6.10] (MSI/MSI-X) – is called.	`KP_IntAtIrql` [B.6.8] and `KP_IntAtIrqlMSI` [B.6.10] run at a high priority, and therefore should perform only the basic interrupt handling, such as lowering the HW interrupt signal of level-sensitive interrupts to acknowledge the interrupt. If more interrupt processing is required, `KP_IntAtIrql` (legacy interrupts) or `KP_IntAtIrqlMSI` (MSI/MSI-X) can return `TRUE` in order to defer additional processing to the relevant deferred processing interrupt handler – `KP_IntAtDpc` [B.6.9] or `KP_IntAtDpcMSI` [B.6.11].
Event: Your application calls `WDC_IntDisable`() [B.3.47], or the low-level `InterruptDisable`() or `WD_IntDisable`() functions (see the **WinDriver PCI Low-Level API Reference**), when the interrupts were previously enabled in the Kernel PlugIn (see the description of the interrupt enable event above).	
Callback: Your `KP_IntDisable` Kernel PlugIn routine [B.6.7] is called.	This function should free any memory that was allocated by the `KP_IntEnable` callback [B.6.6].

11.5.4.4. Interrupt Handling – Deferred Procedure Calls

Event/Callback	Notes
Event: The Kernel PlugIn high-IRQL interrupt handler – `KP_IntAtIrql` [B.6.8] or `KP_IntAtIrqlMSI` [B.6.10] – returns `TRUE`.	This informs WinDriver that additional interrupt processing is required as a Deferred Procedure Call (DPC) in the kernel.
Callback: Your Kernel PlugIn DPC interrupt handler – `KP_IntAtDpc` [B.6.9] (legacy interrupts) or `KP_IntAtDpcMSI` [B.6.11] (MSI/MSI-X) – is called.	Processes the rest of the interrupt code, but at a lower priority than the high-IRQL interrupt handler.
Event: The DPC interrupt handler – `KP_IntAtDpc` [B.6.9] or `KP_IntAtDpcMSI` [B.6.11] – returns a value greater than 0.	This informs WinDriver that additional user-mode interrupt processing is required.
Callback: `WD_IntWait`() (see the **WinDriver PCI Low-Level API Reference**) returns.	Your user-mode interrupt handler routine is executed.

11.5.4.5. Plug-and-Play and Power Management Events

Event/Callback	Notes
Event: Your application registers to receive Plug-and-Play and power management notifications using a Kernel PlugIn driver, by calling `WDC_EventRegister()` [B.3.49] with the with the `fUseKP` parameter set to `TRUE` (after having opened the device with a Kernel PlugIn), or calls the low-level `EventRegister()` (see the **WinDriver PCI Low-Level API Reference**) or `WD_EventRegister()` functions with a handle to a Kernel PlugIn driver (set in the `hKernelPlugIn` field of the `WD_EVENT` structure that is passed to the function).	
Event: A Plug-and-Play or power management event (to which the application registered to listen) occurs.	
Callback: Your `KP_Event` Kernel PlugIn routine [B.6.5] is called.	`KP_Event` receives information about the event that occurred and can proceed to handle it as needed.
Event: `KP_Event` [B.6.5] returns `TRUE`.	This informs WinDriver that the event also requires user-mode handling.
Callback: `WD_IntWait()` (see the **WinDriver PCI Low-Level API Reference**) returns.	Your user-mode event handler routine is executed.

11.6. How Does Kernel PlugIn Work?

The following sections take you through the development cycle of a Kernel PlugIn driver.

It is recommended that you first write and debug your entire driver code in the user mode. Then, if you encounter performance problems or require greater flexibility, port portions of your code to a Kernel PlugIn driver.

11.6.1. Minimal Requirements for Creating a Kernel PlugIn Driver

To build a Kernel PlugIn driver you need the following tools:

- On **Windows 7/Vista/Server 2008/Server 2003/XP**: The Windows Driver Kit (WDK), including its C build tools.

The WDK is available as part of a Microsoft Development Network (MSDN) subscription, or from Microsoft Connect. For more information, see http://www.microsoft.com/whdc/devtools/WDK/WDKpkg.mspx.

- On **Mac OS X**:
  - Xcode matching the Mac OS X version on the development machine [3.1.3]
- On **Linux**:
  - **GCC**, **gmake** or **make**

While this is not a minimal requirement, when developing a Kernel PlugIn driver it is highly recommended that you use two computers: set up one computer as your host platform and the other as your target platform. The host computer is the computer on which you develop your driver and the target computer is the computer on which you run and test the driver you develop.

11.6.2. Kernel PlugIn Implementation

11.6.2.1. Before You Begin

The functions described in this section are callback functions, implemented in the Kernel PlugIn driver, which are called when their calling event occurs – see Section 11.5.4 for details. For example, `KP_Init` [B.6.1] is the callback function that is called when the driver is loaded.

The name of your driver is given in `KP_Init`. The Kernel PlugIn driver's implementation of this callback must be named `KP_Init`. The names of the other Kernel PlugIn callback functions (which are passed to `KP_Init`) are left to the discretion of the driver developer. It is the convention of this reference guide to refer to these callbacks using the format `KP_<Functionality>` – for example, `KP_Open`.
When generating Kernel PlugIn code with the DriverWizard, the names of the callback functions (apart from `KP_Init`) conform to the following format: **KP_<Driver Name>_<Functionality>**. For example, if you named your project **MyDevice**, the name of your Kernel PlugIn `KP_Call` callback will be `KP_MyDevice_Call`.

11.6.2.2. Write Your KP_Init Function

Your `KP_Init` function [B.6.1] should be of the following prototype:

```
BOOL __cdecl KP_Init (KP_INIT *kpInit);
```

This function is called once, when the driver is loaded. The function should fill the received `KP_INIT` structure [B.7.4] with the name of the Kernel PlugIn driver, the name of the WinDriver Kernel PlugIn driver library, and the driver's `KP_Open` callback(s) [B.6.2] (see example in **WinDriver/samples/pci_diag/kp_pci/kp_pci.c**).

- The name that you select for your Kernel PlugIn driver – by setting it in the `cDriverName` field of the `KP_INIT` structure [B.7.4] that is passed to `KP_Init` [B.6.1] – should be the name of the driver that you wish to create; i.e., if you are creating a driver called **XXX.sys**, you should set the name "XXX" in the `cDriverName` field of the `KP_INIT` structure.

- You should verify that the driver name that is used when opening a handle to the Kernel PlugIn driver in the user mode [12.4] – in the `pKPOpenData` parameter of the `WDC_KernelPlugInOpen()` [B.3.17] or `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) functions, or in the `pcDriverName` field of the `pKernelPlugIn` parameter passed to the low-level `WD_KernelPlugInOpen()` function – is identical to the driver name that was set in the `cDriverName` field of the `KP_INIT` structure [B.7.4] that is passed to `KP_Init` [B.6.1].
  The best way to implement this is to define the driver name in a header file that is shared by the user-mode application and the Kernel PlugIn driver and use the defined value in all relevant locations.

From the **KP_PCI** sample (**WinDriver/samples/pci_diag/kp_pci/kp_pci.c**):

```
/* KP_Init is called when the Kernel PlugIn driver is loaded.
   This function sets the name of the Kernel PlugIn driver and the driver's
   open callback function(s). */
BOOL __cdecl KP_Init(KP_INIT *kpInit)
{
    /* Verify that the version of the WinDriver Kernel PlugIn library
        is identical to that of the windrvr.h and wd_kp.h files */
    if (WD_VER != kpInit->dwVerWD)
    {
        /* Rebuild your Kernel PlugIn driver project with the compatible
           version of the WinDriver Kernel PlugIn library (kp_nt<version>.lib)
           and windrvr.h and wd_kp.h files */
        return FALSE;
    }

    kpInit->funcOpen = KP_PCI_Open;
    kpInit->funcOpen_32_64 = KP_PCI_VIRT_Open_32_64;
    strcpy (kpInit->cDriverName, KP_PCI_DRIVER_NAME);

    return TRUE;
}
```

Note that the driver name in the sample is set using a preprocessor definition. This definition is found in the **WinDriver/samples/pci_diag/pci_lib.h** header file, which is shared by the **pci_diag** user-mode application and the **KP_PCI** Kernel PlugIn driver:

```
/* Kernel PlugIn driver name (should be no more than 8 characters) */
#define KP_PCI_DRIVER_NAME "KP_PCI"
```

11.6.2.3. Write Your KP_Open Function(s)

You can implement either one or two `KP_Open` functions, depending on your target configuration [B.6.2]. The `KP_Open` function(s) should be of the following prototype:

```
BOOL __cdecl KP_Open (
    KP_OPEN_CALL *kpOpenCall,
    HANDLE hWD,
    PVOID pOpenData,
    PVOID *ppDrvContext);
```

This callback is called when opening a handle to the Kernel PlugIn driver from the user mode – i.e., when `WD_KernelPlugInOpen`() is called, either directly or via `WDC_KernelPlugInOpen`() [B.3.17] or `WDC_xxxDeviceOpen`() (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]), as explained in Section 12.4.

In the `KP_Open` function, define the callbacks that you wish to implement in the Kernel PlugIn.

The following is a list of the callbacks that can be implemented:

Callback	Functionality
`KP_Close` [B.6.3]	Called when the `WD_KernelPlugInClose`() function (see the **WinDriver PCI Low-Level API Reference**) is called from the user mode – either directly, or via one of the high-level `WDC_xxxDeviceClose`() functions (PCI [B.3.13] / PCMCIA [B.3.14] / ISA [B.3.15]) when called for a device that contains an open Kernel PlugIn handle [12.4].
`KP_Call` [B.6.4]	Called when the user-mode application calls the `WDC_CallKerPlug`() function [B.3.18] or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**), which is called by the wrapper `WDC_CallKerPlug`() function. This function implements a Kernel PlugIn message handler.

Callback	Functionality
KP_IntEnable [B.6.6]	Called when the user-mode application enables Kernel PlugIn interrupts, by calling WDC_IntEnable() with the fUseKP parameter set to TRUE (after having opened a Kernel PlugIn handle), or by calling the low-level InterruptEnable() or WD_IntEnable() functions (see the **WinDriver PCI Low-Level API Reference**) with a handle to a Kernel PlugIn driver (set in the hKernelPlugIn field of the WD_INTERRUPT structure that is passed to the function). This function should contain any initialization required for your Kernel PlugIn interrupt handling.
KP_IntDisable [B.6.7]	Called when the user-mode application calls WDC_IntDisable() [B.3.47], or the low-level InterruptDisable() or WD_IntDisable() functions (see the **WinDriver PCI Low-Level API Reference**), if the interrupts were previously enabled with a Kernel PlugIn driver (see the description of KP_IntEnable above). This function should free any memory that was allocated by the KP_IntEnable callback [B.6.6].
KP_IntAtIrql [B.6.8]	Called when WinDriver receives a legacy interrupt, provided the received interrupt was enabled with a handle to the Kernel PlugIn. This is the function that will handle your legacy interrupt in the kernel mode. The function runs at high interrupt request level. Additional deferred processing of the interrupt can be performed in KP_IntAtDpc and also in the user mode (see below).

Callback	Functionality
`KP_IntAtDpc` [B.6.9]	Called if the `KP_IntAtIrql` callback [B.6.8] has requested deferred handling of a legacy interrupt by returning `TRUE`. This function should include lower-priority kernel-mode interrupt handler code. The return value of this function determines the amount of times that the application's user-mode interrupt handler routine will be invoked (if at all).
`KP_IntAtIrqlMSI` [B.6.10]	Called when WinDriver receives an MSI or MSI-X, provided MSI/MSI-X was enabled for the received interrupt with a handle to the Kernel PlugIn. This is the function that will handle your MSI/MSI-X in the kernel mode. The function runs at high interrupt request level. Additional deferred processing of the interrupt can be performed in `KP_IntAtDpcMSI` and also in the user mode (see below). Note: MSI/MSI-X is supported on Linux, Mac OS X, and Windows Vista and higher.
`KP_IntAtDpcMSI` [B.6.11]	Called if the `KP_IntAtIrqlMSI` callback [B.6.10] has requested deferred handling of an MSI/MSI-X interrupt by returning `TRUE`. This function should include lower-priority kernel-mode MSI/MSI-X handler code. The return value of this function determines the amount of times that the application's user-mode interrupt handler routine will be invoked (if at all). Note: MSI/MSI-X is supported on Linux, Mac OS X, and Windows Vista and higher.

Callback	Functionality
KP_Event [B.6.5]	Called when a Plug-and-Play or power management event occurs, provided the user-mode application previously registered to receive notifications for this event in the Kernel PlugIn by calling WDC_EventRegister() [B.3.49] with the fUseKP parameter set to TRUE (after having opened a Kernel PlugIn handle), or by calling the low-level EventRegister() (see the **WinDriver PCI Low-Level API Reference**) or WD_EventRegister() functions with a handle to a Kernel PlugIn driver (set in the hKernelPlugIn field of the WD_EVENT structure that is passed to the function).

As indicated above, these handlers will be called (respectively) when the user-mode program opens/closes a handle to Kernel PlugIn driver [12.4], sends a message to the Kernel PlugIn driver (by calling WDC_CallKerPlug() / WD_KernelPlugInCall()), enables interrupts with a Kernel PlugIn driver (by calling WDC_IntEnable() with the fUseKP parameter set to TRUE, after having opened a handle to the Kernel PlugIn / calling InterruptEnable() or WD_InterruptEnable() with a handle to the Kernel PlugIn set in the hKernelPlugIn field of the WD_INTERRUPT structure that is passed to function), or disables interrupts (WDC_IntDisable()/ InterruptDisable() / WD_IntDisable()) that have been enabled using a Kernel PlugIn driver;
The Kernel PlugIn interrupt handlers will be called when an interrupt occurs, if the interrupts were enabled using a Kernel PlugIn driver (see above).
The Kernel PlugIn event handler will be called when a Plug-and-Play or power management event occurs, if the application registered to receive notifications for the event that occurred using a Kernel PlugIn driver (by calling WDC_EventRegister() with the fUseKP parameter set to TRUE, after having opened the device with a Kernel PlugIn / calling EventRegister() (see the **WinDriver PCI Low-Level API Reference**) or WD_EventRegister() with a handle to a Kernel PlugIn driver set in the hKernelPlugIn field of the WD_EVENT structure that is passed to the function).

In addition to defining the Kernel PlugIn callback functions, you can implement code to perform any required initialization for the Kernel PlugIn in your KP_Open callback(s) [B.6.2]. In the sample **KP_PCI** driver and in the generated DriverWizard Kernel PlugIn driver, for example, the Kernel PlugIn open callbacks also call the shared library's initialization function and allocate memory for the Kernel PlugIn driver context, which is then used to store the device information that was passed to the function from the user mode.

From the **KP_PCI** sample (**WinDriver/samples/pci_diag/kp_pci/kp_pci.c**):

```
/* KP_PCI_Open is called when WD_KernelPlugInOpen() is called from the
   user mode.
   pDrvContext will be passed to the rest of the Kernel PlugIn callback
   functions. */
BOOL __cdecl KP_PCI_Open(KP_OPEN_CALL *kpOpenCall, HANDLE hWD, PVOID pOpenData,
    PVOID *ppDrvContext)
{
    PCI_DEV_ADDR_DESC *pDevAddrDesc;
    WDC_ADDR_DESC *pAddrDesc;
    DWORD dwSize;
    DWORD dwStatus;

    /* Initialize the PCI library */
    dwStatus = PCI_LibInit();
    if (WD_STATUS_SUCCESS != dwStatus)
    {
        KP_PCI_Err("KP_PCI_Open: Failed to initialize the PCI library: %s",
            PCI_GetLastErr());
        return FALSE;
    }

    KP_PCI_Trace("KP_PCI_Open entered. PCI library initialized.\n");

    kpOpenCall->funcClose = KP_PCI_Close;
    kpOpenCall->funcCall = KP_PCI_Call;
    kpOpenCall->funcIntEnable = KP_PCI_IntEnable;
    kpOpenCall->funcIntDisable = KP_PCI_IntDisable;
    kpOpenCall->funcIntAtIrql = KP_PCI_IntAtIrql;
    kpOpenCall->funcIntAtDpc = KP_PCI_IntAtDpc;
    kpOpenCall->funcIntAtIrqlMSI = KP_PCI_IntAtIrqlMSI;
    kpOpenCall->funcIntAtDpcMSI = KP_PCI_IntAtDpcMSI;
    kpOpenCall->funcEvent = KP_PCI_Event;

    /* Create a copy of device information in the driver context */
    dwSize = sizeof(PCI_DEV_ADDR_DESC);
    pDevAddrDesc = malloc(dwSize);
    if (!pDevAddrDesc)
        goto malloc_error;

    COPY_FROM_USER(pDevAddrDesc, pOpenData, dwSize);
    dwSize = sizeof(WDC_ADDR_DESC) * pDevAddrDesc->dwNumAddrSpaces;
    pAddrDesc = malloc(dwSize);
    if (!pAddrDesc)
        goto malloc_error;

    COPY_FROM_USER(pAddrDesc, pDevAddrDesc->pAddrDesc, dwSize);
    pDevAddrDesc->pAddrDesc = pAddrDesc;
    *ppDrvContext = pDevAddrDesc;

    KP_PCI_Trace("KP_PCI_Open: Kernel PlugIn driver opened successfully\n");

    return TRUE;

malloc_error:
    KP_PCI_Err("KP_PCI_Open: Failed allocating %ld bytes\n", dwSize);
    if (pDevAddrDesc)
        free(pDevAddrDesc);
    PCI_LibUninit();
    return FALSE;
}
```

The **KP_PCI** sample also defines a similar `KP_PCI_Open_32_64` callback, for use when opening a handle to a 64-bit Kernel PlugIn from a 32-bit application.

11.6.2.4. Write the Remaining PlugIn Callbacks

Implement the remaining Kernel PlugIn routines that you wish to use (such as the `KP_Intxxx` functions – for handling interrupts, or `KP_Event` – for handling Plug-and-Play and power management events).

11.6.3. Sample/Generated Kernel PlugIn Driver Code Overview

You can use DriverWizard to generate a skeletal Kernel PlugIn driver for your device, and use the generated code as the basis for your Kernel PlugIn driver development (recommended); alternatively, you can use one of the Kernel PlugIn WinDriver samples as the basis for your Kernel PlugIn development.

The Kernel PlugIn documentation in this manual focuses on the generated DriverWizard code, and the generic PCI Kernel PlugIn sample – **KP_PCI**, located in the **WinDriver/samples/pci_diag/kp_pci** directory.
If you are using the a PCI Express card with the Xilinx Bus Master DMA (BMD) design, you can also use the specific **KP_BMD** Kernel PlugIn sample as the basis for your development. The **WinDriver/xilinx/bmd_design** directory contains all the relevant sample files; (see the note at the end of Section 11.6.4.1 regarding the directory's structure).

The Kernel PlugIn driver is not a standalone module. It requires a user-mode application that initiates the communication with the driver. A relevant application will be generated for your driver when using DriverWizard to generate Kernel PlugIn code. The **pci_diag** application (found under the **WinDriver/samples/pci_diag** directory) communicates with the sample **KP_PCI** driver.

Both the **KP_PCI** sample and the generated wizard code demonstrate communication between a user-mode application (**pci_diag** / **xxx_diag** – where **xxx** is the name you selected for your generated driver project) and a Kernel PlugIn driver (**kp_pci.sys/.o/.ko/.kext** / **kp_xxx.sys/.o/.ko/.kext** – depending on the OS).

The sample/generated code demonstrates how to pass data to the Kernel PlugIn's `KP_Open` function and how to use this function to allocate and store a global Kernel PlugIn driver context, which can be used by other functions in the Kernel PlugIn.

The sample/generated Kernel PlugIn code implements a message for getting the driver's version number, in order to demonstrate how to initiate specific functionality in the Kernel PlugIn from the user mode and how to pass data between the Kernel PlugIn driver and a user-mode WinDriver application via messages.

The sample/generated code also demonstrates how to handle interrupts in the Kernel PlugIn. The Kernel PlugIn implements an interrupt counter and interrupt handlers, including deferred processing interrupt handling, which is used to notify the user-mode application of the arrival of every fifth incoming interrupt.
The **KP_PCI** sample's `KP_IntAtIrql` [B.6.8] and `KP_IntAtDpc` [B.6.9] functions demonstrate legacy level-sensitive PCI interrupt handling. As indicated in the comments of the sample `KP_IntAtIrql` function, you will need to modify this function in order to implement the correct code for acknowledging the interrupt on your specific device, since interrupt acknowledgment is hardware-specific. The sample `KP_IntAtIrqlMSI` [B.6.10] and `KP_IntAtDpcMSI` [B.6.11] functions demonstrate handling of Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) (see detailed information in Section 9.2).
The **generated DriverWizard code** will include sample interrupt handler code for the selected device (PCI/PCMCIA/ISA). The generated `KP_IntAtIrql` function will include code to implement any interrupt transfer commands defined in the wizard (by assigning registers read/write commands to the card's interrupt in the **Interrupt** tab). For legacy PCI and PCMCIA interrupts, which need to be acknowledged in the kernel when the interrupt is received (see Section 9.2), it is recommended that you use the wizard to define the commands for acknowledging (clearing) the interrupt, before generating the Kernel PlugIn code, so that the generated code will already include the required code for executing the commands you defined. It is also recommended that you prepare such transfer commands when handling interrupts for hardware that supports MSI/MSI-X, in case enabling of MSI/MSI-X fails and the interrupt handling defaults to using level-sensitive interrupts (if supported by the hardware).
Note: Memory allocated for the transfer commands must remain available until the interrupts are disabled .

In addition, the sample/generated code demonstrates how to receive notifications of Plug-and-Play and power management events in the Kernel PlugIn.

We recommend that you build and run the sample/generated Kernel PlugIn project (and corresponding user-mode application) "as-is" before modifying the code or writing your own Kernel PlugIn driver. Note, however, that you will need to modify or remove the hardware-specific transfer commands in the sample's `KP_IntAtIrql` function, as explained above.

11.6.4. Kernel PlugIn Sample/Generated Code Directory Structure

11.6.4.1. pci_diag and kp_pci Sample Directories

The **KP_PCI** Kernel PlugIn sample code is implemented in the **kp_pci.c** file. This sample driver is part of the WinDriver PCI diagnostics sample – **pci_diag** – which contains, in addition to the **KP_PCI** driver, a user-mode application that communicates with the driver (**pci_diag**) and a shared library that includes API that can be utilized by both the user-mode application and the Kernel PlugIn driver. The source files for this sample are implemented in C.

Following is an outline of the files found in the **WinDriver/samples/pci_diag** directory:

- **kp_pci** – Contains the **KP_PCI** Kernel PlugIn driver files:
  - **kp_pci.c**: The source code of the **KP_PCI** driver.
  - Project and/or make files and related files for building the Kernel PlugIn driver.
    The Windows project files are located in subdirectories for the target IDE (**msdev_***) under **x86** (32-bit) and **amd64** (64-bit) directories.
    The Mac OS X files are located under a **macos** subdirectory.
    For Linux, the makefile is generated using a **configure** script, which is provided directly under the **kp_pci** directory.
  - A pre-compiled version of the **KP_PCI** Kernel PlugIn driver for the target OS:
    - Windows x86 32-bit: **WINNT.i386\kp_pci.sys** – a 32-bit version of the driver, built for Windows XP and higher.
    - Windows x64: **WINNT.x86_64\kp_pci.sys** – a 64-bit version of the driver, built for Windows Server 2003 and higher.
    - Mac OS X: **macos/kp_pci.kext**.
    - Linux: There is no pre-compiled version of the driver for Linux, since Linux kernel modules must be compiled with the header files from the kernel version installed on the target – see Section 14.5.
- **pci_lib.c**: Implementation of a library for accessing PCI devices using WinDriver's WDC API [B.2]. The library's API is used both by the user-mode application (**pci_diag.c**) and by the Kernel PlugIn driver (**kp_pci.c**).
- **pci_lib.h**: Header file, which provides the interface for the **pci_lib** library.
- **pci_diag.c**: Implementation of a sample diagnostics user-mode console (CUI) application, which demonstrates communication with a PCI device using the **pci_lib** and **WDC** libraries. The sample also demonstrates how to communicate with a Kernel PlugIn driver from a user-mode WinDriver application. By default, the sample attempts to open the selected PCI device with a handle to the **KP_PCI** Kernel PlugIn driver. If successful, the sample demonstrates how to interact with a Kernel PlugIn driver, as detailed in Section 11.6.3. If the application fails to open a handle to the Kernel PlugIn driver, all communication with the device is performed from the user mode.
- **pci.inf** (Windows): A sample WinDriver PCI INF file for Windows. NOTE: To use this file, change the vendor and device IDs in the file to comply with those of your specific device.

To use Message-Signaled Interrupts (MSI) or Extended Message-Signaled Interrupts (MSI-X) on Windows Vista and higher (for PCI cards that support MSI/MSI-X) you will need to modify or replace the sample INF file so that your INF file includes specific MSI information; otherwise WinDriver will attempt to use legacy level-sensitive interrupt handling for your card, as explained in Section 9.2.6.1 of the manual.

- Project and/or make files for building the **pci_diag** user-mode application.
  The Windows project files are located in subdirectories for the target IDE (**msdev_*** / **cbuilder***) under **x86** (32-bit) and **amd64** (64-bit) directories. The **msdev_*** MS Visual Studio directories also include workspace/solution files for building both the Kernel PlugIn driver and user-mode application projects.
  Project and/or makefiles for other supported operating systems are located under OS subdirectories – **macos** for Mac OS X and **LINUX** for Linux.

- A pre-compiled version of the user-mode application (**pci_diag**) for your target operating system:

  - Windows: **WIN32\pci_diag.exe**

  - Mac OS X: **macos/build/Release/pci_diag**

  - Linux: **LINUX/pci_diag**

- **files.txt**: A list of the sample **pci_diag** files.

- **readme.txt**: An overview of the sample Kernel PlugIn driver and user-mode application and instructions for building and testing the code.

The structure of the sample directory for PCI Express cards with the Xilinx Bus Master DMA (BMD) design – **WinDriver/xilinx/bmd_design** – is similar to that of the generic PCI sample's **pci_diag** directory, except for the following issues: the **bmd_diag** user-mode application files are located under a **diag** subdirectory, and the **kp** subdirectory, which contains the Kernel PlugIn driver's (**KP_BMD**) source files, currently has make files only for Windows.

11.6.4.2. The Generated DriverWizard Kernel PlugIn Directory

The generated DriverWizard Kernel PlugIn code for your device will include a kernel-mode Kernel PlugIn project and a user-mode application that communicates with it. As opposed to the generic **KP_PCI** and **pci_diag** sample, the generated wizard code will utilize the resources information detected and/or defined for your specific device, as well as any device-specific information that you define in the wizard before generating the code.

As indicated in Section 11.6.3, when using the driver to handle legacy PCI or PCMCIA interrupts, it is highly recommended that you define the registers that need to be read/written in order to acknowledge the interrupt, and set up the relevant read/write commands from/to these registers in DriverWizard, before generating the code, thus enabling the generated interrupt handler code to utilize the hardware-specific information that you defined. It is also recommended that you prepare such transfer commands when handling interrupts for hardware that supports MSI/MSI-X, in case enabling of MSI/MSI-X fails and the interrupt handling defaults to using level-sensitive interrupts (if supported by the hardware).
Note: Memory allocated for the transfer commands must remain available until the interrupts are disabled .

Following is an outline of the generated DriverWizard files when selecting to generate Kernel PlugIn code (where **xxx** signifies the name that you selected for the driver when generating the code). NOTE: The outline below relates to the generated C code, but on Windows you can also generate similar C# code, which includes a C Kernel PlugIn driver (since kernel-mode drivers cannot be implemented in C#), a .NET C# library, and a C# user-mode application that communicates with the Kernel PlugIn driver.

- **kermode** – Contains the **KP_XXX** Kernel PlugIn driver files:
  - **kp_xxx.c**: The source code of the **KP_XXX** driver.
  - Project and/or make files and related files for building the Kernel PlugIn driver.
    The Windows project files are located in subdirectories for the target IDE (**msdev_***) under **x86** (32-bit) and **amd64** (64-bit) directories.
    Project and/or makefiles for other supported operating systems are located under **<os>** subdirectories – **macos** for Mac OS X and **linux** for Linux; for Linux, the makefile is generated using a **configure** script, which is provided in the **linux** subdirectory.
- **xxx_lib.c**: Implementation of a library for accessing your device using WinDriver's WDC API [B.2]. The library's API is used both by the user-mode application (**xxx_diag**) and by the Kernel PlugIn driver (**KP_XXX**).
- **xxx_lib.h**: Header file, which provides the interface for the **xxx_lib** library.
- **xxx_diag.c**: Implementation of a sample diagnostics user-mode console (CUI) application, which demonstrates communication your device using the **xxx_lib** and **WDC** libraries.
  The application also demonstrates how to communicate with a Kernel PlugIn driver from a user-mode WinDriver application. By default, the application attempts to open your device with a handle to the **KP_XXX** Kernel PlugIn driver. If successful, the application demonstrates how to interact with a Kernel PlugIn driver, as detailed in Section 11.6.3. If the application fails to open a handle to the Kernel PlugIn driver, all communication with the device is performed from the user mode.
- Project and/or make files for building the **xxx_diag** user-mode application.
  The Windows project files are located in subdirectories for the target IDE (**msdev_*** / **cbuilder***) under **x86** (32-bit) and **amd64** (64-bit) directories. The **msdev_*** MS Visual Studio directories also include workspace/solution files for building both the Kernel PlugIn driver and user-mode application projects.
  Project and/or make files for other supported operating systems are located under **<os>** subdirectories – **macos** for Mac OS X and **linux** for Linux.
- **xxx_files.txt**: A list of the generated files and instructions for building the code.
- **xxx.inf** (Windows): A WinDriver INF file for your device. This file is required only when creating a Windows driver for a Plug-and-Play device, such as PCI and PCMCIA.

11.6.5. Handling Interrupts in the Kernel PlugIn

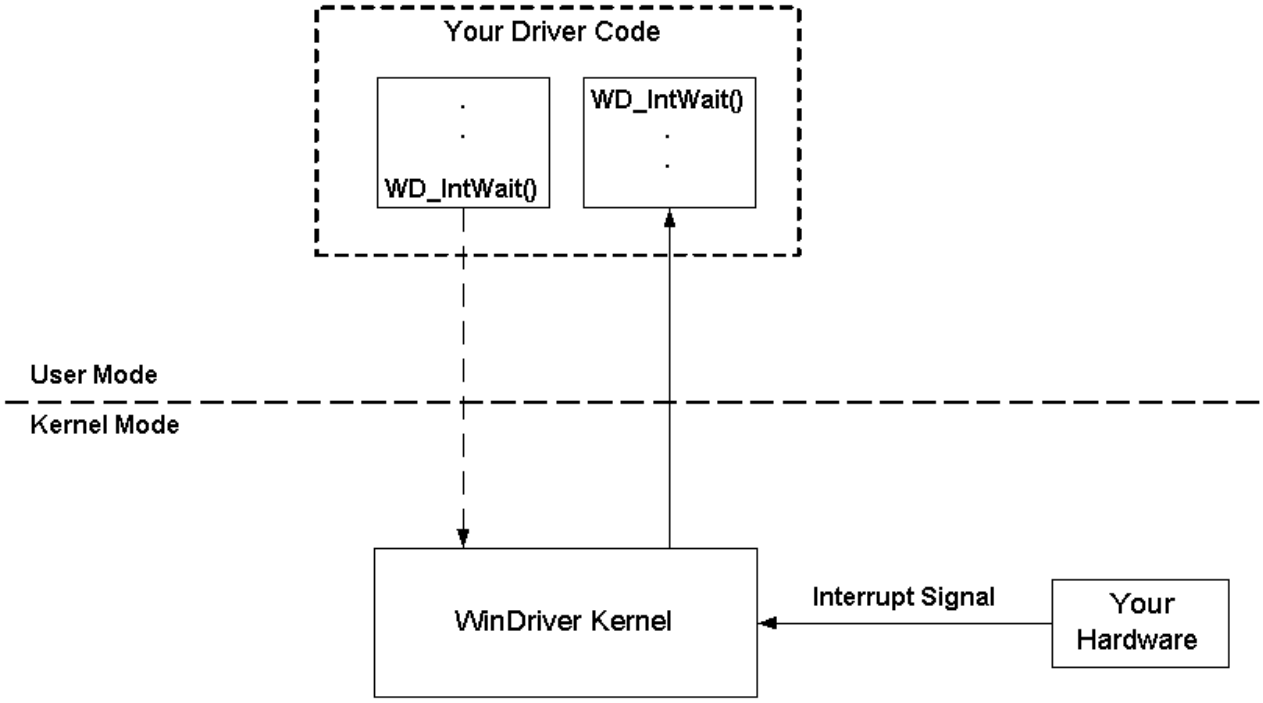
Interrupts will be handled in the Kernel PlugIn driver, if enabled, using a Kernel PlugIn driver, as explained below [11.6.5.2].

If Kernel PlugIn interrupts were enabled, when WinDriver receives a hardware interrupt, it calls the Kernel PlugIn driver's high-IRQL handler – `KP_IntAtIrql` [B.6.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.6.10] (MSI/MSI-X). If the high-IRQL handler returns `TRUE`, the relevant deferred Kernel PlugIn interrupt handler – `KP_IntAtDpc` [B.6.9] (legacy interrupts) or `KP_IntAtDpcMSI` [B.6.11] (MSI/MSI-X) – will be called after the high-IRQL handler completes its processing and returns. The return value of the DPC function determines how many times (if at all) the user-mode interrupt handler routine will be executed. In the **KP_PCI** sample, for example, the Kernel PlugIn interrupt handler code counts five interrupts, and notifies the user mode on every fifth interrupt; thus `WD_IntWait`() (see the **WinDriver PCI Low-Level API Reference**) will return on only one out of every five incoming interrupts in the user mode. The high-IRQL handler – `KP_IntAtIrql` [B.6.8] or `KP_IntAtIrqlMSI` [B.6.10] – returns `TRUE` every five interrupts to activate the DPC handler – `KP_IntAtDpc` or `KP_IntAtDpcMSI` – and the DPC function returns the number of accumulated DPC calls from the high-IRQL handler. As a result, the user-mode interrupt handler will be executed once for every 5 interrupts.

11.6.5.1. Interrupt Handling in the User Mode (Without Kernel PlugIn)

If the Kernel PlugIn interrupt handle is not enabled, then each incoming interrupt will cause `WD_IntWait`() to return and your user-mode interrupt handler routine will be invoked once WinDriver completes the kernel processing of the interrupts (mainly executing the interrupt transfer commands passed in the call to `WDC_IntEnable`() [B.3.46] or the low-level `InterruptEnable`() or `WD_IntEnable`() functions – see the **WinDriver PCI Low-Level API Reference**) – see Figure 11.2.

Figure 11.2. Interrupt Handling Without Kernel PlugIn

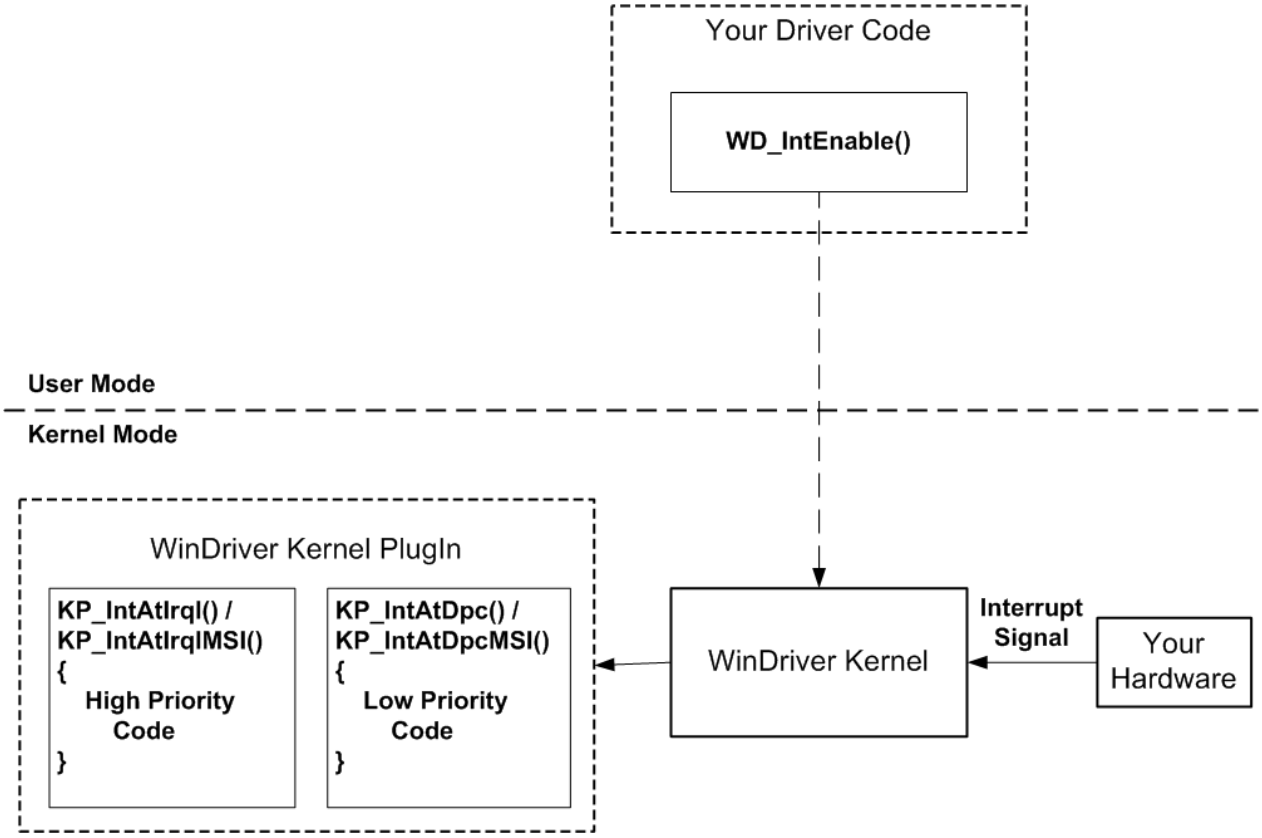


11.6.5.2. Interrupt Handling in the Kernel (Using a Kernel PlugIn)

To have the interrupts handled by the Kernel PlugIn, the user-mode application should open a handle to a Kernel PlugIn driver (as explained in Section 12.4), and then call `WDC_IntEnable()` [B.3.46] with the `fUseKP` parameter set to `TRUE`.

If your are not using the `WDC_xxx` API [B.2], your application should pass a handle to the Kernel PlugIn driver to the `WD_IntEnable()` function or the wrapper `InterruptEnable()` function (which calls `WD_IntEnable()` and `WD_IntWait()`). This enables the Kernel PlugIn interrupt handler. (The Kernel PlugIn handle is passed within the `hKernelPlugIn` field of the `WD_INTERRUPT` structure that is passed to the functions.) For details regarding the low-level `WD_xxx()` API, refer to the **WinDriver PCI Low-Level API Reference**.

Figure 11.3. Interrupt Handling With the Kernel PlugIn



When calling `WDC_IntEnable()` / `InterruptEnable()` / `WD_IntEnable()` to enable interrupts in the Kernel PlugIn, your Kernel PlugIn's `KP_IntEnable` callback function [B.6.6] is activated. In this function you can set the interrupt context that will be passed to the Kernel PlugIn interrupt handlers, as well as write to the device to actually enable the interrupts in the hardware and implement any other code required in order to correctly enable your device's interrupts.

If the Kernel PlugIn interrupt handler is enabled, then the relevant high-IRQL handler, based on the type of interrupt that was enabled – `KP_IntAtIrql` [B.6.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.6.10] (MSI/MSI-X) – will be called for each incoming interrupt. The code in the high-IRQL handler is executed at high interrupt request level. While this code is running, the system is halted, i.e., there will be no context switches and no lower-priority interrupts will be handled.

© Jungo Ltd. 2005–2011

Code running at high IRQL is limited in the following ways:

- It may only access non-pageable memory.
- It may only call the following functions (or wrapper functions that call these functions):
  - `WDC_xxx`() read/write address or configuration space functions.
  - `WDC_MultiTransfer`() [B.3.25], or the low-level `WD_Transfer`(), `WD_MultiTransfer`(), or `WD_DebugAdd`() functions (see the **WinDriver PCI Low-Level API Reference**).
  - Specific kernel OS functions (such as WDK functions) that can be called from high interrupt request level. Note that the use of such functions may break the code's portability to other operating systems.
- It may **not** call `malloc`(), `free`(), or any `WDC_xxx` or `WD_xxx` API other than those listed above.

Because of the aforementioned limitations, the code in the high-IRQL handler (`KP_IntAtIrql` [B.6.8] or `KP_IntAtIrqlMSI` [B.6.10]) should be kept to a minimum, such as acknowledgment (clearing) of level-sensitive interrupts. Other code that you want to run in the interrupt handler should be implemented in the DPC function (`KP_IntAtDpc` [B.6.9] or `KP_IntAtDpcMSI` [B.6.11]), which runs at a deferred interrupt level and does not face the same limitations as the high-IRQL handlers. The DPC function is called after its matching high-IRQL function returns, provided the high-IRQL handler returns `TRUE`.

You can also leave some additional interrupt handling to the user mode. The return value of your DPC function – `KP_IntAtDpc` [B.6.9] or `KP_IntAtDpcMSI` [B.6.11] – determines the amount of times (if any) that your user-mode interrupt handler routine will be called after the kernel-mode interrupt processing is completed.

11.6.6. Message Passing

The WinDriver architecture enables a kernel-mode function to be activated from the user mode by passing a message from the user mode to the Kernel PlugIn driver using `WDC_CallKerPlug`() [B.3.18] or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**).
The messages are defined by the developer in a header file that is common to both the user-mode and kernel-mode plugin parts of the driver. In the **pci_diag KP_PCI** sample and the generated DriverWizard code, the messages are defined in the shared library header file – **pci_lib.h** in the sample or **xxx_lib.h** in the generated code.

Upon receiving the message from the user mode, WinDriver will execute the `KP_Call` [B.6.4] Kernel PlugIn callback function, which identifies the message that has been received and executes the relevant code for this message (as implemented in the Kernel PlugIn).

The sample/generated Kernel PlugIn code implement a message for getting the driver's version in order to demonstrate Kernel PlugIn data passing. The code that sets the version number in `KP_Call` is executed in the Kernel PlugIn whenever the Kernel PlugIn receives a relevant message from the user-mode application. You can see the definition of the message in the shared **pci_lib.h** / **xxx_lib.h** shared header file. The user-mode application (**pci_diag.exe** / **xxx_diag.exe**) sends the message to the Kernel PlugIn driver via the `WDC_CallKerPlug`() function [B.3.18].

Chapter 12
Creating a Kernel PlugIn Driver

The easiest way to write a Kernel PlugIn driver is to use **DriverWizard** to generate the Kernel PlugIn code for your hardware (see Sections 11.6.3 and 11.6.4.2). Alternatively, you can use one of the WinDriver **Kernel PlugIn samples** as the basis for your Kernel PlugIn development. You can also develop your code "from scratch", if you wish.

As indicated in Section 11.6.3, the Kernel PlugIn documentation in this manual focuses on the generated DriverWizard code, and the generic PCI Kernel PlugIn sample – **KP_PCI**, located in the **WinDriver/samples/pci_diag/kp_pci** directory.
If you are using the a PCI Express card with the Xilinx Bus Master DMA (BMD) design, you can also use the specific **KP_BMD** Kernel PlugIn sample as the basis for your development. The **WinDriver/xilinx/bmd_design** directory contains all the relevant sample files; (see the note at the end of Section 11.6.4.1 regarding the directory's structure).

The following is a step-by-step guide to creating your Kernel PlugIn driver.

12.1. Determine Whether a Kernel PlugIn is Needed

The Kernel PlugIn should be used only after your driver code has been written and debugged in the user mode. This way, all of the logical problems of creating a device driver are solved in the user mode, where development and debugging are much easier.

Determine whether a Kernel PlugIn should be written by consulting Chapter 10, which explains how to improve the performance of your driver. In addition, the Kernel PlugIn affords greater flexibility, which is not always available when writing the driver in the user mode (specifically with regard to the interrupt handling).

12.2. Prepare the User-Mode Source Code

1. Isolate the functions you need to move into the Kernel PlugIn.

2. Remove any platform-specific code from the functions. Use only functions that can also be used from the kernel.

3. Recompile your driver in the user mode.

4. Debug your driver in user mode again to see that your code still works after changes have been made.

- Keep in mind that the kernel stack is relatively limited in size. Therefore, code that will be moved into the Kernel PlugIn should not contain static memory allocations. Use the `malloc`() function to allocate memory dynamically instead. This is especially important for large data structures.

- If the user-mode code that you are porting to the kernel accesses memory addresses directly using the user-mode mapping of the physical address returned from the low-level `WD_CardRegister`() function – note that in the kernel you will need to use the kernel mapping of the physical address instead (the kernel mapping is also returned by `WD_CardRegister`()). For details, refer to the description of `WD_CardRegister`() in the **WinDriver PCI Low-Level API Reference**.
  When using the API of the **WDC** library [B.2] to access memory, you do not need to worry about this, since this API ensures that the correct mapping of the memory is used depending on whether the relevant APIs are used from the user mode or from the kernel mode.

12.3. Create a New Kernel PlugIn Project

As indicated above, you can use **DriverWizard** to generate a new Kernel PlugIn project (and corresponding user-mode project) for your device (recommended), or use the **KP_PCI** sample as the basis for your development.

To successfully build a Kernel PlugIn project using MS Visual Studio, the path to the project directory must not contain any spaces.

If you select to use the **KP_PCI** sample as the basis for your development, follow these steps:

1. Make a copy of the **WinDriver/samples/pci_diag/kp_pci** directory. For example, to create a new Kernel PlugIn project called **KP_MyDrv**, copy **WinDriver/samples/pci_diag/kp_pci** to **WinDriver/samples/mydrv**.

2. Change all instances of "KP_PCI" and "kp_pci", in all the Kernel PlugIn files in your new directory, to "KP_MyDrv" and "kp_mydrv" (respectively).
   The names of the `KP_PCI_xxx`() functions in the **kp_pci.c** files do not have to be changed, but the code will be clearer if you use your selected driver name in the function names.

3. Change all occurrences of "KP_PCI" in file names to "kp_mydrv".

4. To use the shared **pci_lib** library API from your Kernel PlugIn driver and user-mode application, copy the **pci_lib.h** and **pci_lib.c** files from the **WinDriver/samples/pci_diag** directory to your new **mydrv** directory. You can change the names of the library functions to use your driver's name (**MyDrv**) instead of "PCI", but note that in this case you will also need to modify the names in all calls to these functions from your Kernel PlugIn project and user-mode application. If you do not copy the shared library to your new project, you will need to modify the sample Kernel PlugIn code and replace all references to the `PCI_xxx` library APIs with alternative code.

© Jungo Ltd. 2005–2011

5. Modify the files and directory paths in the project and make files, and the #include paths in the source files, as needed (depending on the location in which you selected to save your new project directory).

6. To use the **pci_diag** user-mode application, copy **WinDriver/samples/pci_diag/pci_diag.c** and the relevant pci_diag project, workspace/solution or make files to your **mydrv** directory, rename the files (if you wish), and replace all "pci_diag" references in the files with your preferred user-mode application name. To use the workspace/solution files, also replace the references to "KP_PCI" in the files with your new Kernel PlugIn driver, e.g., "KP_MyDrv". Then modify the sample code to implement your desired driver functionality.

For a general description of the sample and generated Kernel PlugIn code and its structure, see Sections 11.6.3 and 11.6.4 (respectively).

12.4. Open a Handle to the Kernel PlugIn

To open a handle to a Kernel PlugIn driver, `WD_KernelPlugIn`() (see the **WinDriver PCI Low-Level API Reference**) needs to be called from the user mode. This low-level function is called both from `WDC_KernelPlugInOpen`() [B.3.17], and from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) – when they are called with the name of a Kernel PlugIn driver.

When using the high-level WDC API [B.2] you can use either of the following methods to open a Kernel PlugIn handle:

- First open a regular device handle – by calling the relevant `WDC_xxxDeviceOpen`() function without the name of a Kernel PlugIn driver. Then call `WDC_KernelPlugInOpen`(), passing to it the handle to the opened device. `WDC_KernelPlugInOpen`() opens a handle to the Kernel PlugIn driver, and stores it within the `kerPlug` field of the provided device structure [B.4.3].

- Open a handle to the device, using the relevant `WDC_xxxDeviceOpen`() function, and pass the name of a Kernel PlugIn driver within the function's `pcKPDriverName` parameter. The device handle returned by the function will also contain (within the `kerPlug` field) a Kernel PlugIn handle opened by the function.

This method *cannot* be used to open a handle to a 64-bit Kernel PlugIn driver from a 32-bit application, or to open a Kernel PlugIn handle from a .NET application.

To ensure that your code works correctly in all the supported configurations, use the first method described above.

The generated DriverWizard and the sample **pci_diag** shared library (**xxx_lib.c** / **pci_lib.c**) demonstrate how to open a handle to the Kernel PlugIn – see the generated/sample `XXX_DeviceOpen`()/`PCI_DeviceOpen`() library function (which is called from the generated/sample **xxx_diag**/**pci_diag** user-mode application).

The handle to the Kernel PlugIn driver is closed when the WD_KernelPlugInClose() function (see the **WinDriver PCI Low-Level API Reference**) is called from the user mode. When using the low-level WinDriver API, this function is called directly from the user-mode application. When using the high-level WDC API [B.2], the function is called automatically when calling WDC_xxxDeviceClose() (PCI [B.3.13] / PCMCIA [B.3.14] / ISA [B.3.15]) with a device handle that contains an open Kernel PlugIn handle. The function is also called by WinDriver as part of the application cleanup, for any identified open Kernel PlugIn handles.

12.5. Set Interrupt Handling in the Kernel PlugIn

1. When calling WDC_IntEnable() [B.3.46] (after having opened a handle to the Kernel PlugIn driver, as explained in Section 12.4), set the fUseKP function parameter to TRUE to indicate that you wish to enable interrupts in the Kernel PlugIn driver with which the device was opened.
   The generated DriverWizard and the sample **pci_diag** shared library (**xxx_lib.c** / **pci_lib.c**) demonstrate how this should be done – see the generated/sample XXX_IntEnable()/PCI_IntEnable() library function (which is called from the generated/sample **xxx_diag**/**pci_diag** user-mode application).

   If you are not using the WDC_xxx API [B.2], in order to enable interrupts in the Kernel PlugIn call WD_IntEnable() or InterruptEnable() (which calls WD_IntEnable()), and pass the handle to the Kernel PlugIn driver that you received from WD_KernelPlugInOpen() (within the hKernelPlugIn field of the WD_KERNEL_PLUGIN structure that was passed to the function). For details regarding these APIs, refer to the **WinDriver PCI Low-Level API Reference**.

2. When calling WDC_IntEnable() / InterruptEnable() / WD_IntEnable(), to enable interrupts in the Kernel PlugIn, WinDriver will activate your Kernel PlugIn's KP_IntEnable callback function [B.6.6]. You can implement this function to set the interrupt context that will be passed to the high-IRQL and DPC Kernel PlugIn interrupt handler routines, as well as write to the device to actually enable the interrupts in the hardware, for example, or implement any other code required in order to correctly enable your device's interrupts.

3. Move the implementation of the user-mode interrupt handler, or the relevant portions of this implementation, to the Kernel PlugIn's interrupt handler functions. High-priority code, such as the code for acknowledging (clearing) level-sensitive interrupts, should be moved to the relevant high-IRQL handler – KP_IntAtIrql [B.6.8] (legacy interrupts) or KP_IntAtIrqlMSI [B.6.10] (MSI/MSI-X) – which runs at high interrupt request level. Deferred processing of the interrupt can be moved to the relevant DPC handler – KP_IntAtDpc [B.6.9] or KP_IntAtDpcMSI [B.6.11] – which will be executed once the high-IRQL handler completes it processing and returns TRUE. You can also modify the code to make it more efficient, due to the advantages of handling the interrupts directly in the kernel, which provides you with greater flexibility (e.g., you can read from a specific register and write back the value that was read, or toggle specific register bits). For a

detailed explanation on how to handle interrupts in the kernel using a Kernel PlugIn, refer to Section 11.6.5 of the manual.

12.6. Set I/O Handling in the Kernel PlugIn

1. Move your I/O handling code (if needed) from the user mode to the Kernel PlugIn message handler – `KP_Call` [B.6.4].

2. To activate the kernel code that performs the I/O handling from the user mode, call `WDC_CallKerPlug`() [B.3.18] or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**) with a relevant message for each of the different functionality that you wish to perform in the Kernel PlugIn.
   Implement a different message for each functionality.

3. Define these messages in a header file that is shared by the user-mode application (which will send the messages) and the Kernel PlugIn driver (that implements the messages).
   In the sample/generated DriverWizard Kernel PlugIn projects, the message IDs and other information that should be shared by the user-mode application and Kernel PlugIn drive are defined in the **pci_lib.h**/**xxx_lib.h** shared library header file.

12.7. Compile Your Kernel PlugIn Driver

The Kernel PlugIn is not backwards compatible. Therefore, when switching to a different version of WinDriver, you need to rebuild your Kernel PlugIn driver using the new version.

12.7.1. On Windows

The sample **WinDriver\samples\pci_diag\kp_pci** Kernel PlugIn directory and the generated DriverWizard Kernel PlugIn **<project_dir>\kermode** directory (where **<project_dir>** is the directory in which you selected to save the generated driver project) contain the following **Kernel PlugIn** project files (where **xxx** is the driver name – **pci** for the sample / the name you selected when generating the code with the wizard):

- **x86** – 32-bit project files:
  - **msdev_2010\kp_xxx.vcproj** – 32-bit MS Visual Studio 2010 project.
  - **msdev_2008\kp_xxx.vcproj** – 32-bit MS Visual Studio 2008 project.
  - **msdev_2005\kp_xxx.vcproj** – 32-bit MS Visual Studio 2005 project.
  - **msdev_2003\kp_xxx.vcproj** – 32-bit MS Visual Studio 2003 project.
  - **msdev_6\kp_xxx.dsp** – 32-bit MS Visual Studio 6.0 project.

- **amd64** – 64-bit project files:
  - **msdev_2010\kp_xxx.vcproj** – 64-bit MS Visual Studio 2010 project.
  - **msdev_2008\kp_xxx.vcproj** – 64-bit MS Visual Studio 2008 project.
  - **msdev_2005\kp_xxx.vcproj** – 64-bit MS Visual Studio 2005 project.

The sample **WinDriver\samples\pci_diag** directory and the generated **<project_dir>** directory contain the following project files for the **user-mode** application that drives the respective Kernel PlugIn driver (where **xxx** is the driver name – **pci** for the sample / the name you selected when generating the code with the wizard):

- **x86** – 32-bit project files:
  - **msdev_2010\xxx_diag.vcproj** – 32-bit MS Visual Studio 2010 project.
  - **msdev_2008\xxx_diag.vcproj** – 32-bit MS Visual Studio 2008 project.
  - **msdev_2005\xxx_diag.vcproj** – 32-bit MS Visual Studio 2005 project.
  - **msdev_2003\xxx_diag.vcproj** – 32-bit MS Visual Studio 2003 project.
  - **msdev_6\xxx_diag.dsp** – 32-bit MS Visual Studio 6.0 project.
  - **cbuilder4\xxx.bpr** and **xxx.cpp** – Borland C++ Builder 4.0 project file and related CPP file. These files can also be used from version 5.0 and 6.0 of Borland C++ Builder.
  - **cbuilder3\xxx.bpr** and **xxx.cpp** – Borland C++ Builder 3.0 project file and related CPP file.
- **amd64** – 64-bit project files:
  - **msdev_2010\xxx_diag.vcproj** – 64-bit MS Visual Studio 2010 project.
  - **msdev_2008\xxx_diag.vcproj** – 64-bit MS Visual Studio 2008 project.
  - **msdev_2005\xxx_diag.vcproj** – 64-bit MS Visual Studio 2005 project.

The **msdev_*** MS Visual Studio directories listed above also contain **xxx_diag.dsw/.sln** workspace/solution files that include both the **Kernel PlugIn** and **user-mode** projects.

To build your Kernel PlugIn driver and respective user-mode application on Windows, follow these steps:

1. Verify that the Windows Driver Kit (WDK) is installed.
2. Set the **BASEDIR** environment variable to point to the location of the directory in which WDK is installed.

© Jungo Ltd. 2005–2011

3. Start Microsoft Visual Studio, and do the following:

   a. From your driver project directory, open the Kernel PlugIn workspace/solution file – **<project_dir>\msdev_*\xxx_diag.dsw/.sln**, where **<project_dir>** is your driver project directory (**pci_diag** for the sample code / the directory in which you selected to save the generated DriverWizard code), **msdev_*** is your target Visual Studio directory (e.g., **msdev_2010**), and **xxx** is the driver name (**pci** for the sample / the name you selected when generating the code with the wizard).

   - When using DriverWizard to generate code for MS Visual Studio, you can use the *IDE to Invoke* option to have the wizard automatically open the generated workspace/solution file in your selected IDE, after generating the code files.
   - To successfully build a Kernel PlugIn project using MS Visual Studio, the path to the project directory must not contain any spaces.

   b. To build the **Kernel PlugIn SYS driver** (**kp_pci.sys** – sample / **kp_xxx.sys** – generated wizard code):

      1. Set the Kernel PlugIn project (**kp_pci.dsp/vcproj** / **kp_xxx.dsp/vcproj**) as the active project.

      2. Select the active configuration for your target platform: From the **Build** menu, choose **Configuration Manager...** (Visual Studio 2003/2005/2008) / **Set Active Configuration...** (Visual Studio 6.0), and select the desired configuration.

         To build the driver for multiple operating systems, select the lowest OS version that the driver must support. For example, to support Windows XP and higher, select either **Win32 winxp free** (release mode) or **Win32 winxp checked** (debug mode).

      3. Build your driver: Build the project from the **Build** menu or using the relevant shortcut key (e.g., **F7** in Visual Studio 6.0).

   c. To build the **user-mode application** that drives the Kernel PlugIn driver (**pci_diag.exe** – sample / **xxx_diag.exe** – generated wizard code):

      1. Set the user-mode project (**pci_diag.dsp/vcproj** – sample / **xxx_diag.dsp/vcproj** – generated wizard code) as the active project.

      2. Build the application: Build the project from the **Build** menu or using the relevant shortcut key (e.g., **F7** in Visual Studio 6.0).

© Jungo Ltd. 2005–2011

12.7.2. On Mac OS X

In the following instructions

- **<project_dir>** signifies the path to the project directory that contains your Kernel PlugIn and/or user-mode application – for example, **~/WinDriver/wizard/my_projects/my_kp** for a generated "my_kp" project, or **~/WinDriver/samples/pci_diag** for the KP_PCI sample.

- **<KP_dir>** signifies the directory that contains your Kernel PlugIn files – **<project_dir>/kermode** for the generated DriverWizard Kernel PlugIn projects, or **WinDriver/samples/pci_diag/kp_pci** for the KP_PCI sample.

- **xxx** signifies the name of your Kernel PlugIn project – i.e., the project name you selected when generating the code with DriverWizard, or **pci** for the KP_PCI sample.

To build your Kernel PlugIn driver and respective user-mode application on Mac OS X, follow these steps:

1. Build the Kernel PlugIn: Open your Kernel PlugIn project with Xcode, and build the code. The Kernel PlugIn project folder is located at **<KP_dir>/macos/kp_xxx.xcodeproj** – e.g., **~/WinDriver/wizard/my_projects/my_kp/kermode/macos/KP_MY_KP.xcodeproj** (for a MY_KP generated DriverWizard project), or **~/WinDriver/samples/pci_diag/kp_pci/macos/kp_pci.xcodeproj** (for the KP_PCI sample).

   The build will create a **kp_xxx.kext** Kernel PlugIn kernel extension folder under a **<KP_dir>/macos/build/Release** or **<KP_dir>/macos/build/Debug** subdirectory – depending on how you selected to build the project. For example, **~/WinDriver/wizard/my_projects/my_kp/kermode/macos/build/Release/kp_my_kp.kext** or **~/WinDriver/samples/pci_diag/kp_pci/macos/build/Release/kp_pci.kext**.

2. Build the user-mode application that drives your Kernel PlugIn project, using either of these methods:

   - Use Xcode to open the **<project_dir>/macos/xxx.xcodeproj** application project – for example, **~/WinDriver/wizard/my_projects/my_kp/macos/my_kp.xcodeproj** or **~/WinDriver/samples/pci_diag/macos/pci_diag** – and build the code.

   - Open a command-line prompt, change directory to the **<project_dir>/macos** directory – for example, **~/WinDriver/wizard/my_projects/my_kp/macos** or **~/WinDriver/samples/pci_diag/macos** – and run `make` to build the code.

   The build will create an **xxx** application under a **<project_dir>/macos/build/Release** or **<project_dir>/macos/build/Debug** subdirectory – depending on how you selected to build the project. For example, **~/WinDriver/wizard/my_projects/my_kp/macos/build/Release/my_kp** or **~/WinDriver/samples/pci_diag/macos/build/Release/pci_diag**.

© Jungo Ltd. 2005–2011

12.7.3. On Linux

To build your Kernel PlugIn driver and respective user-mode application on Linux, follow these steps:

1. Open a shell terminal.

2. Change directory to your Kernel PlugIn directory.

   For example:

   - When compiling the sample **KP_PCI** driver, run this command:
     `cd WinDriver/samples/pci_diag/kp_pci`

   - When compiling the Kernel PlugIn driver for your generated DriverWizard Kernel PlugIn code, run the following command, where **<path>** signifies the path to your generated DriverWizard project directory (for example, **/home/user/WinDriver/wizard/my_projects/my_kp**):
     `cd <path>/kermode/linux/`

3. Generate the **makefile** using the **configure** script:

   ```
   ./configure --disable-usb-support
   ```

   The **configure** script creates a **makefile** based on your specific running kernel. You may run the **configure** script based on another kernel source you have installed, by adding the flag `--with-kernel-source=<path>` to the configure script. The <path> is the full path to the kernel source directory, e.g., **/usr/src/linux**.
   If the Linux kernel version is 2.6.26 or higher, **configure** generates makefiles that use **`kbuild`** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by passing the **`--enable-kbuild`** flag to **configure**.

4. Build the Kernel PlugIn module using the **`make`** command.
   This command creates a new **LINUX.xxx** directory (where **xxx** depends on the Linux kernel), which contains the created **kp_xxx_module.o/.ko** driver.

5. Move to the directory that holds the makefile for the sample user-mode diagnostics application.

   For the **KP_PCI** sample driver:
   `cd ../LINUX/`

   For the generated DriverWizard Kernel PlugIn driver:
   `cd ../../linux/`

6. Compile the sample diagnostics program using the **`make`** command.

12.8. Install Your Kernel PlugIn Driver

12.8.1. On Windows

Driver installation on Windows requires administrator privileges.

1. Copy the driver file (**xxx.sys**) to the target platform's drivers directory: **%windir%\system32\drivers** (e.g., **C:\WINDOWS\system32\drivers**).

2. Register/load your driver, using the **wdreg.exe** or **wdreg_gui.exe** utility:

   In the following instructions, **KP_NAME** stands for your Kernel PlugIn driver's name, *without* the .sys extension.

   To install your driver, run:

   ```
   WinDriver\util> wdreg -name KP_NAME install
   ```

Kernel PlugIn drivers are dynamically loadable, and thus do not require a reboot in order to load.

12.8.2. On Mac OS X

Driver installation on Mac OS X requires root privileges.

To install your Kernel PlugIn driver on Mac OS X, run the following command from a command-line prompt:

```
$ sudo <path to wdreg>
<KP_dir>/macos/build/<Release/Debug>/kp_xxx.kext
```

For example:

- For a generated DriverWizard **MY_KP** Kernel PlugIn project:

  ```
  $ sudo ~/WinDriver/redist/wdreg ~/WinDriver/wizard/my_projects/
  my_kp/kermode/macos/build/Release/kp_my_kp.kext
  ```

- For the **KP_PCI** sample:

  ```
  $ sudo ~/WinDriver/redist/wdreg
  ~/WinDriver/samples/pci_diag/kp_pci/macos/build/Release/
  kp_pci.kext
  ```

© Jungo Ltd. 2005–2011

12.8.3. On Linux

1. Change directory to your Kernel PlugIn driver directory.

   For example, when installing the sample **KP_PCI** driver, run:
   `cd WinDriver/samples/pci_diag/kp_pci`

   When installing a driver created using the Kernel PlugIn files generated by DriverWizard, run the following command, where **<path>** signifies the path to your generated DriverWizard project directory (e.g., **/home/user/WinDriver/wizard/my_projects/my_kp**):
   `cd <path>/kermode/`

2. Execute the following command to install your Kernel PlugIn driver:

   The following command must be executed with root privileges.

   `make install`

Chapter 13
Dynamically Loading Your Driver

13.1. Why Do You Need a Dynamically Loadable Driver?

When adding a new driver, you may be required to reboot the system in order for it to load your new driver into the system. WinDriver is a dynamically loadable driver, which enables your customers to start your application immediately after installing it, without the need for reboot. You can dynamically load your driver whether you have created a user-mode or a kernel-mode (Kernel PlugIn [11]) driver.

To successfully unload your driver, make sure that there are no open handles to the WinDriver service (**windrvr6.sys** or your renamed driver (refer to Section 15.2), and that there are no connected and enabled Plug-and-Play devices that are registered with this service.

13.2. Windows Dynamic Driver Loading

13.2.1. Windows Driver Types

Windows drivers can be implemented as either of the following types:

- Windows Driver Model (WDM) drivers: Files with the extension ***.sys** on Windows 7/Vista/ Server 2008/Server 2003/XP/2000/Me/98 (e.g., **windrvr6.sys**).
  WDM drivers are installed via the installation of an INF file (see below).

- Non-WDM / Legacy drivers: These include drivers for non-Plug-and-Play Windows operating systems (Windows NT 4.0) and files with the extension ***.vxd** on Windows 98/Me, as well as all Kernel PlugIn driver files (e.g., **MyKPDriver.sys**).

Starting from version 6.2.1 of WinDriver, ***.vxd** drivers are no longer supported.

The WinDriver Windows kernel module – **windrvr6.sys** – is a fully WDM driver, which can be installed using the **wdreg** utility, as explained in the following sections.

13.2.2. The wdreg Utility

WinDriver provides a utility for dynamically loading and unloading your driver, which replaces the slower manual process using Windows' Device Manager (which can still be used for the device INF). This utility is provided in two forms: **wdreg** and **wdreg_gui**. Both versions can be found in the **WinDriver\util** directory, can be run from the command line, and provide the same functionality. The difference is that **wdreg_gui** displays installation messages graphically, while **wdreg** displays them in console mode.

This section describes the use of **wdreg**/ **wdreg_gui** on Windows operating systems.

1. **wdreg** is dependent on the Driver Install Frameworks API (**DIFxAPI**) DLL – **difxapi.dll**, unless when run with the `-compat` option (described below). **difxapi.dll** is provided under the **WinDriver\util** directory.

2. The explanations and examples below refer to **wdreg**, but any references to **wdreg** can be replaced with **wdreg_gui**.

13.2.2.1. WDM Drivers

This section explains how to use the **wdreg** utility to install the WDM **windrvr6.sys** driver on Windows, or to install INF files that register Plug-and-Play devices (such as PCI or PCMCIA) to work with this driver on Windows 7/Vista/Server 2008/Server 2003/XP.

You can rename the **windrvr6.sys** kernel module and modify your device INF file to register with your renamed driver, as explained in Section 15.2.1. To install your modified INF files using **wdreg**, simply replace any references to **windrvr6** below with the name of your new driver.

This section is **not relevant** for **Kernel PlugIn** drivers, since these are not WDM drivers and are not installed via an INF file. For an explanation on how to use **wdreg** to install Kernel PlugIn drivers on Windows 7 / Vista / Server 2008 / Server 2003 / XP, refer to Section 13.2.2.2.

Usage: The **wdreg** utility can be used in two ways as demonstrated below:

1. ```
   wdreg -inf <filename> [-silent] [-log <logfile>]
     [install | preinstall | uninstall | enable | disable]
   ```

2. ```
   wdreg -rescan <enumerator> [-silent] [-log <logfile>]
   ```

- OPTIONS
  wdreg supports several basic OPTIONS from which you can choose one, some, or none:

  - **-inf** – The path of the INF file to be dynamically installed.

  - **-rescan <enumerator>** – Rescan enumerator (ROOT, ACPI, PCI, etc.) for hardware changes. Only one enumerator can be specified.

© Jungo Ltd. 2005–2011

- **-silent** – Suppress display of all messages (optional).
- **-log <logfile>** – Log all messages to the specified file (optional).
- **-compat** – Use the traditional **SetupDi** API instead of the newer Driver Install Frameworks API (**DIFxAPI**).

- ACTIONS
  wdreg supports several basic ACTIONS:
  - **install** – Installs the INF file, copies the relevant files to their target locations, and dynamically loads the driver specified in the INF file name by replacing the older version (if needed).
  - **preinstall** Pre-installs the INF file for a non-present device.
  - **uninstall** – Removes your driver from the registry so that it will not load on next boot (see note below).
  - **enable** – Enables your driver.
  - **disable** – Disables your driver, i.e., dynamically unloads it, but the driver will reload after system boot (see note below).

To successfully disable/uninstall your driver, make sure that there are no open handles to the WinDriver service (**windrvr6.sys** or your renamed driver (refer to Section 15.2), and that there are no connected and enabled Plug-and-Play devices that are registered with this service.

13.2.2.2. Non-WDM Drivers

This section explains how to use the **wdreg** utility to install non-WDM drivers, namely Kernel PlugIn drivers, on Windows 7/Vista/Server 2008/Server 2003/XP.

Usage:

```
wdreg [-file <filename>] [-name <drivername>] [-startup <level>]
[-silent] [-log <logfile>] Action [Action ...]
```

- OPTIONS
  wdreg supports several basic OPTIONS from which you can choose one, some, or none:
  - **-startup**: Specifies when to start the driver. Requires one of the following arguments:
    - **boot**: Indicates a driver started by the operating system loader, and should only be used for drivers that are essential to loading the OS (for example, Atdisk).
    - **system**: Indicates a driver started during OS initialization.

- **automatic**: Indicates a driver started by the Service Control Manager during system startup.
- **demand**: Indicates a driver started by the Service Control Manager on demand (i.e., when your device is plugged in).
- **disabled**: Indicates a driver that cannot be started.

The default setting for the **-startup** option is **automatic**.

- **-name** – Sets the symbolic name of the driver. This name is used by the user-mode application to get a handle to the driver. You must provide the driver's symbolic name (*without* the *.sys extension) as an argument with this option. The argument should be equivalent to the driver name as set in the `KP_Init` [B.6.1] function of your Kernel PlugIn project: **`strcpy(kpInit->cDriverName, XX_DRIVER_NAME)`** .
- **-file** – **wdreg** allows you to install your driver in the registry under a different name than the physical file name. This option sets the file name of the driver. You must provide the driver's file name (*without* the *.sys extension) as an argument.
  wdreg looks for the driver in the Windows installation directory (**%windir%\system32\drivers**). Therefore, you should verify that the driver file is located in the correct directory before attempting to install the driver.

  Usage:
  `wdreg -name <Your new driver name> -file <Your original driver name> install`
- **-silent** – Suppresses the display of messages of any kind.
- **-log <logfile>** – Logs all messages to the specified file.

- ACTIONS
  wdreg supports several basic ACTIONS:
  - **create** – Instructs Windows to load your driver next time it boots, by adding your driver to the registry.
  - **delete** – Removes your driver from the registry so that it will not load on next boot.
  - **start** – Dynamically loads your driver into memory for use. You must create your driver before starting it.
  - **stop** – Dynamically unloads your driver from memory.
- Shortcuts
  wdreg supports a few shortcut operations for your convenience:

© Jungo Ltd. 2005–2011

- **install** – Creates and starts your driver.
  This is the same as first using the wdreg **`stop`** action (if a version of the driver is currently loaded) or the wdreg **`create`** action (if no version of the driver is currently loaded), and then the wdreg **`start`** action.

- **preinstall** – Creates and starts your driver for a non-connected device.

- **uninstall** – Unloads your driver from memory and removes it from the registry so that it will not load on next boot.
  This is the same as first using the wdreg **`stop`** action and then the wdreg **`delete`** action.

13.2.3. Dynamically Loading/Unloading windrvr6.sys INF Files

When using WinDriver, you develop a user-mode application that controls and accesses your hardware by using the generic **windrvr6.sys** driver (WinDriver's kernel module). Therefore, you might want to dynamically load and unload the driver **windrvr6.sys** – which you can do using **wdreg**.
In addition, in WDM-compatible operating systems, you also need to dynamically load INF files for your Plug-and-Play devices. **wdreg** enables you to do so automatically on Windows 7/ Vista/Server 2008/Server 2003/XP.
This section includes **wdreg** usage examples, which are based on the detailed description of **wdreg** contained in the previous section. Examples:

- To start **windrvr6.sys** on Windows 7/Vista/Server 2008/Server 2003/XP:
  `wdreg -inf <path to windrvr6.inf> install`
  This command loads **windrvr6.inf** and starts the **windrvr6.sys** service.

- To load an INF file named **device.inf**, located in the **c:\tmp** directory:
  `wdreg -inf c:\tmp\device.inf install`

  You can replace the **`install`** option in the example above with **`preinstall`** to pre-install the device INF file for a device that is not currently connected to the PC.

If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

To unload the driver/INF file, use the same commands, but simply replace **`install`** in the examples above with **`uninstall`**.

13.2.4. Dynamically Loading/Unloading Your Kernel PlugIn Driver

If you have used WinDriver to develop a Kernel PlugIn driver, you must load your Kernel PlugIn after loading the WinDriver generic driver **windrvr6.sys**.
When uninstalling your driver, you should unload your Kernel PlugIn driver before unloading **windrvr6.sys**.

Kernel PlugIn drivers are dynamically loadable, and thus do not require a reboot in order to load.

To load/unload your Kernel PlugIn driver (**<Your driver name>.sys**) use the **wdreg** command as described above for windrvr6, with the addition of the 'name' flag, after which you must add the name of your Kernel PlugIn driver.

You should **not** add the *.sys extension to the driver name.

Examples:

- To load a Kernel PlugIn driver called **KPDriver.sys**, run this command:
  ```
  wdreg -name KPDriver install
  ```
- To load a Kernel PlugIn driver called MPEG_Encoder, with file name **MPEGENC.sys**, run this command:
  ```
  wdreg -name MPEG_Encoder -file MPEGENC install
  ```
- To uninstall a Kernel PlugIn driver called **KPDriver.sys**, run this command:
  ```
  wdreg -name KPDriver uninstall
  ```
- To uninstall a Kernel PlugIn driver called MPEG_Encoder, with file name MPEGENC.sys, run this command:
  ```
  wdreg -name MPEG_Encoder -file MPEGENC uninstall
  ```

13.3. Mac OS X Dynamic Driver Loading

13.3.1. Dynamically Loading Your Driver on Mac OS X

Normally, to load a driver kernel extension dynamically on Mac OS X, you need to use the OS's **kextload** utility, as super user (root), and point the utility to the location of the kernel extension folder. The entire path to the kernel extension folder must be owned by root:wheel, with permissions non-writable by group and other – *rwxr-xr-x* (*755*).
One way to ensure the necessary permissions, is to copy the driver's kernel extension folder, as super user, to the **/tmp** folder.

To reload the driver automatically on each boot, the kernel extension folder should be copied to the OS's kernel extensions folder: **/System/Library/Extensions**. (Note: On some Mac OS X platforms, the act of copying the kernel extension folder to the **/System/Library/Extensions** folder also loads the driver, in which case running **kextload** will result in a message indicating that the driver is already loaded.)

13.3.1.1. The wdreg Script

WinDriver's **wdreg** installation script simplifies the dynamic driver loading procedure on Mac OS X.
wdreg receives a path to a kernel extension folder; if it locates the extension folder in the specified search path, it copies the extension to the OS's **/tmp** folder in order to ensure the proper permissions, and then uses the OS's **kextload** utility to load the driver; if the extension folder is not found in the search path, **wdreg** searches for the extension in the OS's kernel extensions folder – **/System/Library/Extensions** – and if a matching extension is found, it is installed from this location.

- **wdreg** is provided in the **WinDriver/redist** directory.
- Since driver installation requires root privileges, you must run **wdreg** as super user.
- When using **wdreg**, the name of the kernel extension folder may be specified with or without the **.kext** suffix. For example, **WinDriver.kext** and **WinDriver** are equally valid ways of pointing to WinDriver's **WinDriver.kext** kernel extension folder, using **wdreg**.

To dynamically load a driver using **wdreg**, run the following command:
```
sudo <path to wdreg> <path to the driver's kext folder>
```

As indicated above, if the kernel extension folder is found in the OS's **/System/Library/Extensions** folder, you may omit the path to the extension folder. For example, to dynamically load the WinDriver kernel extension, which has been copied to the **/System/Library/Extensions** folder (as done automatically as part of the WinDriver toolkit installation), run this command:
```
sudo <path to wdreg> WinDriver
```

13.3.2. Dynamically Unloading Your Driver on Mac OS X

To unload a driver dynamically on Mac OS X, you need to run the OS's **kextunload** utility, and provide it with the path to the driver's kernel extension folder:
```
sudo kextunload <path to the driver's kext folder>
```

- **kextunload** must be run with root privileges.
- You must provide **kextunload** with the full path to the kernel extension folder, and provide the full extension name – including the **.kext** suffix.

For example, to unload the WinDriver kernel extension, which has been copied to the **/System/Library/Extensions** folder, run the following command:
`sudo kextunload /System/Library/Extensions/WinDriver.kext`

13.4. Linux Dynamic Driver Loading

The following commands must be executed with root privileges.

- To dynamically load WinDriver, run the following command:
  `<path to wdreg> windrvr6`

- To dynamically unload WinDriver, run the following command:
  `/sbin/modprobe -r windrvr6`.

wdreg is provided in the **WinDriver/util** directory.

To automatically load WinDriver on each boot, add the following to the target Linux boot file (**/etc/rc.d/rc.local**):
`<path to wdreg> windrvr6`

13.5. Windows CE Dynamic Driver Loading

The **WinDriver\redist\Windows_Mobile_5_ARMV4I\wdreg.exe** utility can be used for loading the WinDriver kernel module (**windrvr6.dll**) on a Windows CE platform.

On many versions of Windows CE, the operating system's security scheme prevents the loading of unsigned drivers at boot time, therefore the WinDriver kernel module has to be reloaded after boot. To load WinDriver on the target Windows CE platform every time the OS is started, copy the **wdreg.exe** utility to the **Windows\StartUp** directory on the target PC.

The source code of the Windows CE **wdreg.exe** utility is available under the **WinDriver\samples\wince_install\wdreg** directory on the development PC.

Chapter 14
Distributing Your Driver

Read this chapter in the final stages of driver development. It will guide you in preparing your driver for distribution.

14.1. Getting a Valid License for WinDriver

To purchase a WinDriver license, complete the **WinDriver/docs/order.pdf** order form and fax or email it to Jungo. Complete details are included on the order form. Alternatively, you can order WinDriver online. For more details, visit our web site: http://www.jungo.com.

In order to install the registered version of WinDriver and to activate driver code that you have developed during the evaluation period on the development machine, please follow the installation instructions found in Section 3.2 above.

14.2. Windows Driver Distribution

- All references to **wdreg** in this section can be replaced with **wdreg_gui**, which offers the same functionality as **wdreg** but displays GUI messages instead of console-mode messages.

- If you have renamed the WinDriver kernel module (**windrvr6.sys**), as explained in Section 15.2, replace the relevant **windrvr6** references with the name of your driver, and replace references to the **WinDriver\redist** directory with the path to the directory that contains your modified installation files. For example, when using the generated DriverWizard renamed driver files for your driver project, as explained in Section 15.2.1, you can replace references to the **WinDriver\redist** directory with references to the generated **xxx_installation\redist** directory (where **xxx** is the name of your generated driver project). Note also the option to simplify the installation using the generated DriverWizard **xxx_install.bat** script and the copies of the **WinDriver\util** installation files in the generated **xxx_installation\redist** directory, as explained in Section 15.2.1.

- If you have created new INF and/or catalog files for your driver, replace the references to the original WinDriver INF files and/or to the **wd1040.cat** catalog file with the names of your new files (see the file renaming information in Sections 15.2.1 and 15.3.2).

- If you wish to distribute drivers for both 32-bit and 64-bit target platforms, you must prepare a separate driver installation package for each platform. The required files for each package are located within the WinDriver installation directory for the respective platform.

Distributing the driver you created is a multi-step process. First, create a distribution package that includes all the files required for the installation of the driver on the target computer. Second, install the driver on the target machine. This involves installing **windrvr6.sys** and **windrvr6.inf**, installing the specific INF file for your device (for Plug-and-Play hardware – PCI/PCI Express/ PCMCIA), and installing your Kernel PlugIn driver (if you have created one).

Finally, you need to install and execute the hardware control application that you developed with WinDriver. These steps can be performed using **wdreg** utility.

This section refers to distribution of ***.sys** files. Starting from WinDriver version 6.21 ***.vxd** drivers are no longer supported.

14.2.1. Preparing the Distribution Package

Your distribution package should include the following files:

- Your hardware control application/DLL.
- **windrvr6.sys**.
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **windrvr6.inf**.
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **wd1040.cat**.
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **wdapi1040.dll** (for distribution of 32-bit binaries to 32-bit target platforms or for distribution of 64-bit binaries to 64-bit platforms) or **wdapi1040_32.dll** (for distribution of 32-bit binaries to 64-bit platforms [A.2].
  Get this file from the **WinDriver\redist** directory of the WinDriver package.
- **difxapi.dll** (required by the **wdreg.exe** utility [13.2.2]).
  Get this file from the **WinDriver\util** directory of the WinDriver package.
- An INF file for your device (required for Plug-and-Play devices, such as PCI and PCMCIA). You can generate this file with DriverWizard, as explained in Section 4.2.
- If you have created a Kernel PlugIn driver [11]: Your Kernel PlugIn driver – **<KP driver name>.sys**.

14.2.2. Installing Your Driver on the Target Computer

Driver installation on Windows requires administrator privileges.

Follow the instructions below in the order specified to properly install your driver on the target computer:

- **Preliminary Steps:**
  To successfully install your driver, make sure that there are no open handles to the WinDriver service (**windrvr6.sys** or your renamed driver (refer to Section 15.2), and that there are no connected and enabled Plug-and-Play devices that are registered with this service. This is relevant, for example, when upgrading the version of the driver (for WinDriver v6.0.0 and above; earlier versions used a different module name). If the service is being used, attempts to install the new driver using **wdreg** will fail. You can disable or uninstall connected devices from the Device Manager (**Properties | Disable/Uninstall**) or using **wdreg**, or otherwise physically disconnect the device(s) from the PC.

- **Install WinDriver's kernel module:**

  1. Copy **windrvr6.sys**, **windrvr6.inf**, and **wd1040.cat** to the same directory.

     wd1040.cat contains the driver's Authenticode digital signature. To maintain the signature's validity this file must be found in the same installation directory as the **windrvr6.inf** file. If you select to distribute the catalog and INF files in different directories, or make any changes to these files or to any other files referred to by the catalog file (such as **windrvr6.sys**), you will need to do either of the following:
     - Create a new catalog file and re-sign the driver using this file.
     - Comment-out or remove the following line in the **windrvr6.inf** file:
       `CatalogFile=wd1040.cat`
       and do not include the catalog file in your driver distribution. However, note that this option invalidates the driver's digital signature.

     For more information regarding driver digital signing and certification and the signing of your WinDriver-based driver, refer to Section 15.3 of the manual.

  2. Use the utility **wdreg** to install WinDriver's kernel module on the target computer:
     `wdreg -inf <path to windrvr6.inf> install`

     For example, if **windrvr6.inf** and **windrvr6.sys** are in the **d:\MyDevice** directory on the target computer, the command should be:
     `wdreg -inf d:\MyDevice\windrvr6.inf install`

     You can find the executable of **wdreg** in the WinDriver package under the **WinDriver\util** directory. For a general description of this utility and its usage, please refer to Chapter 13.

     - **wdreg** is dependent on the **difxapi.dll** DLL.
     - **wdreg** is an interactive utility. If it fails, it will display a message instructing the user how to overcome the problem. In some cases the user may be asked to reboot the computer.

When distributing your driver, you should attempt to ensure that the installation does not overwrite a newer version of **windrvr6.sys** with an older version of the file in Windows drivers directory (**%windir%\system32\drivers**) – for example, by configuring your installation program (if you are using one) or your INF file so that the installer automatically compares the time stamp on these two files and does not overwrite a newer version with an older one. The provided **windrvr6.inf** file uses the `COPYFLG_NO_VERSION_DIALOG` directive, which is designed to avoid overwriting a file in the destination directory with the source file if the existing file is newer than the source file. There is also a similar `COPYFLG_OVERWRITE_OLDER_ONLY` INF directive that is designed to ensure that the source file is copied to the destination directory only if the destination file is superseded by a newer version. **Note**, however, that both of these INF directives are irrelevant to digitally signed drivers. As explained in the Microsoft *INF CopyFiles Directive* documentation – http://msdn.microsoft.com/en-us/library/ff546346%28v=vs.85%29.aspx – if a driver package is digitally signed, Windows installs the package as a whole and does not selectively omit files in the package based on other versions already present on the computer. The **windrvr6.sys** driver provided by Jungo is digitally signed (refer to Section 15.3 for more information).

- **Install the INF file for your device** (registering your Plug-and-Play device with **windrvr6.sys**):

  Run the utility **wdreg** with the **`install`** command to automatically install the INF file and update Windows Device Manager:

  ```
  wdreg -inf <path to your INF file> install
  ```

  You can also use the **wdreg** utility's **`preinstall`** command to pre-install an INF file for a device that is not currently connected to the PC:

  ```
  wdreg -inf <path to your INF file> preinstall
  ```

If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

- **Install your Kernel PlugIn driver**: If you have created a Kernel PlugIn driver, install it by following the instructions in Section 14.2.3.

- **Install wdapi1040.dll:**
  If your hardware control application/DLL uses **wdapi1040.dll** (as is the case for the sample and generated DriverWizard WinDriver projects), copy this DLL to the target's **%windir%\system32** directory.
  If you are distributing a 32-bit application/DLL to a target 64-bit platform [A.2], rename **wdapi1040_32.dll** in your distribution package to **wdapi1040.dll**, and copy the renamed file to the target's **%windir%\sysWOW64** directory.

  If you attempt to write a 32-bit installation program that installs a 64-bit program, and therefore copies the 64-bit **wdapi1040.dll** DLL to the **%windir%\system32** directory, you may find that the file is actually copied to the 32-bit **%windir%\sysWOW64** directory. The reason for this is that Windows x64 platforms translate references to 64-bit directories from 32-bit commands into references to 32-bit directories. You can avoid the problem by using 64-bit commands to perform the necessary installation steps from your 32-bit installation program. The **system64.exe** program, provided in the **WinDriver\redist** directory of the Windows x64 WinDriver distributions, enables you to do this.

- **Install your hardware control application/DLL**: Copy your hardware control application/DLL to the target and run it!

14.2.3. Installing Your Kernel PlugIn on the Target Computer

Driver installation on Windows requires administrator privileges.

If you have created a Kernel PlugIn driver, follow the additional instructions below:

1. Copy your Kernel PlugIn driver (**<KP driver name>.sys**) to Windows drivers directory on the target computer (**%windir%\system32\drivers**).

2. Use the utility **wdreg** to add your Kernel PlugIn driver to the list of device drivers Windows loads on boot. Use the following installation command:

   To install a **SYS** Kernel PlugIn Driver:
   ```
   wdreg -name <Your driver name, without the *.sys extension> install
   ```

   You can find the executable of **wdreg** in the WinDriver package under the **WinDriver\util** directory. For a general description of this utility and its usage, please refer to Chapter 13 (see specifically Section 13.2.4 for Kernel PlugIn installation).

14.3. Windows CE Driver Distribution

14.3.1. Distribution to New Windows CE Platforms

The following instructions apply to platform developers who build Windows CE kernel images using Windows CE Platform Builder or using MS Visual Studio 2005/2008 with the appropriate Windows CE plugin. The instructions use the notation **'Windows CE IDE'** to refer to either of these platforms.

To distribute the driver you developed with WinDriver to a new target Windows CE platform, follow these steps:

1. Modify the project registry file to add an entry for your target device:

   - *If you select to use the WinDriver component* (refer to Step 2), modify **WinDriver\samples\wince_install\<TARGET_CPU>\WinDriver.reg** (e.g., **WinDriver\samples\wince_install\ARMV4I\WinDriver.reg**).

   - *Otherwise*, modify **WinDriver\samples\wince_install\project_wd.reg**.

2. *For **Windows CE 4.x–5.x** only*, you can simplify the driver integration into your Windows CE platform by following the procedure described in this step, before the Sysgen platform compilation stage.

   Note:

   - Developers who use Windows CE 6.x and higher should skip to the next step (Step 3).

   - This procedure provides a convenient method for integrating WinDriver into your Windows CE platform. If you select not to use this method, you will need to perform the manual integration steps described in Step 4 below, after the Sysgen stage.

   - The procedure described in this step also adds the WinDriver kernel module (**windrvr6.dll**) to your OS image. This is a necessary step if you want the WinDriver CE kernel file (**windrvr6.dll**) to be a permanent part of the Windows CE image (**NK.BIN**), which is the case if you select to transfer the file to your target platform using a boot disk. However, if you prefer to have the file **windrvr6.dll** loaded on demand via the CESH/ PPSH services, you need to perform the manual integration method described in Step 4 instead of performing the procedure described in the present step.

     a. Run the Windows CE IDE and open your platform.

     b. From the **File** menu select **Manage Catalog Items....**, click the **Import...** button, and select the **WinDriver.cec** file from the relevant **WinDriver\samples\wince_install\<TARGET_CPU>** directory (e.g., **WinDriver\samples\wince_install\ARMV4I**). This will add a WinDriver component to the Platform Builder Catalog.

c. In the **Catalog** view, right-click the mouse on the **WinDriver Component** node in the **Third Party** tree, and select **Add to OS design**.

3. Compile your Windows CE platform (Sysgen stage).

4. If you did not perform the procedure described in Step 2 above, perform the following steps after the Sysgen stage in order to manually integrate the driver into your platform.
Note: If you followed the procedure described in Step 2, skip this step and go directly to Step 5.

   a. Run the Windows CE IDE and open your platform.

   b. Select **Open Release Directory** from the **Build** menu.

   c. Copy the WinDriver CE kernel file – **WinDriver\redist\<TARGET_CPU>\windrvr6.dll** – to the **%_FLATRELEASEDIR%** subdirectory on the target development platform (should be the current directory in the new command window).

   d. Append the contents of **WinDriver\samples\wince_install\project_wd.reg** to the **%_FLATRELEASEDIR%\project.reg** registry file.

   e. Copy the contents of the **WinDriver\samples\wince_install\project_wd.bib** file to the FILES section of the binary image builder file – **%_FLATRELEASEDIR%\project.bib**. Then uncomment the line that matches the target platform (see the "TODO" comments in the copied text).

This step is only necessary if you want the WinDriver CE kernel file (**windrvr6.dll**) to be a permanent part of the Windows CE image (**NK.BIN**), which is the case if you select to transfer the file to your target platform using a boot disk. If you prefer to have the file **windrvr6.dll** loaded on demand via the CESH/PPSH services, you do not need to perform this step until you build a permanent kernel.

5. Select **Make Run-Time Image** from the **Build** menu, and name the new image **NK.BIN**.

6. Download your new kernel to the target platform and initialize it either by selecting **Attach Device** from the **Target** menu, or by using a boot disk. For Windows CE 4.x, the menu is called **Download/Initialize** rather than **Attach Device**.

7. Restart your target CE platform. The WinDriver CE kernel will automatically load.

8. Install your hardware control application/DLL on the target.
If your hardware control application/DLL uses **wdapi1040.dll** (as is the case for the sample and generated DriverWizard WinDriver projects), also copy this DLL from the **WinDriver\redist\WINCE\<TARGET_CPU>** directory on the Windows host development PC to the target's **Windows** directory.

© Jungo Ltd. 2005–2011

14.3.2. Distribution to Windows CE Computers

Unless otherwise specified, 'Windows CE' references in this section include all supported Windows CE platforms, including Windows Mobile.

1. Copy WinDriver's kernel module – **windrvr6.dll** – from the **WinDriver\redist\WINCE\<TARGET_CPU>** directory on the Windows host development PC to the **Windows** directory on your target Windows CE platform.

2. Add WinDriver to the list of device drivers Windows CE loads on boot:

   - Modify the registry according to the entries documented in the file **WinDriver\samples\wince_install\project_wd.reg**. This can be done using the Windows CE Pocket Registry Editor on the hand-held CE computer, or by using the Remote CE Registry Editor Tool supplied with MS eMbedded Visual C++ or MS Visual Studio 2005/2008. Note that in order to use the Remote CE Registry Editor tool you will need to have Windows CE Services installed on your Windows host platform.

   - On many versions of Windows CE, the operating system's security scheme prevents the loading of unsigned drivers at boot time, therefore the WinDriver kernel module has to be reloaded after boot. To load WinDriver on the target Windows CE platform every time the OS is started, copy the **WinDriver\redist\Windows_Mobile_5_ARMV4I\wdreg.exe** utility to the **Windows\StartUp** directory on the target PC.

3. Restart your target CE computer. The WinDriver CE kernel will automatically load. You will have to do a warm reset rather than just suspend/resume (use the reset or power button on your target CE computer).

4. Install your hardware control application/DLL on the target.
   If your hardware control application/DLL uses **wdapi1040.dll** (as is the case for the sample and generated DriverWizard WinDriver projects), also copy this DLL from the **WinDriver\redist\WINCE\<TARGET_CPU>** directory on the development PC to the target's **Windows** directory.

© Jungo Ltd. 2005–2011

14.4. Mac OS X Driver Distribution

- If you have renamed the WinDriver kernel module (**WinDriver.kext**), as explained in Section 15.2, replace the relevant **WinDriver** references with the name of your driver, and replace references to the **~/WinDriver/redist** folder with the path to the location of the modified installation files. For example, when using the generated DriverWizard renamed driver files for your driver project, as explained in Section 15.2.2, you can replace references to **~/WinDriver/redist** with the path to the generated **xxx_installation/redist** folder (where **xxx** is the name of your generated driver project).

- If you wish to distribute drivers for both 32-bit and 64-bit target platforms, you must prepare a separate driver installation package for each platform. The required files for each package are located within the WinDriver installation directory for the respective platform.

14.4.1. Preparing the Distribution Package

Before distributing your driver, prepare a distribution package that includes the following files:

- The WinDriver kernel extension – **WinDriver.kext**, or your renamed version of this extension [15.2].
  Get this file from the **~/WinDriver/redist** folder.

- The WinDriver API framework – **WDAPI.framework**.
  Get this file from the **~/WinDriver/redist** folder.

- If you have created a Kernel PlugIn driver [11]: Your Kernel PlugIn kernel extension – **<KP driver name>.kext**.

- The **wdreg** installation script [13.3.1.1].
  Get this file from the **~/WinDriver/redist** folder.

- Your hardware-control application/framework.

14.4.2. Installing Your Driver on the Target Computer

Driver installation on Mac OS X requires root privileges.

To install your driver on the target computer, follow these steps:

1. **Install the WinDriver kernel module:**

   a. Copy the WinDriver kernel extension folder – **WinDriver.kext**, or your renamed version of this extension [15.2] – to the target's **/System/Library/Extensions** folder (optional).

- Copying the extension to the this location requires root:wheel ownership with permissions non-writable by group and other – *rwxr-xr-x* (*755*).
- This step is optional, but it is recommended, since it ensures that the driver will be loaded automatically on each boot, and it eliminates the need to provide the full extension path in the **wdreg** installation command (see Step b).

b. Install the driver using the **wdreg** installation script [13.3.1.1]:

```
$ sudo <path to wdreg> <path to the driver's kext folder>
```

- The extension name can be specified with or without the **.kext** extension.
- When installing the driver from the OS's extensions folder – **/System/Library/Extensions** – you do not need to specify the full extension path in the installation command. For example, if you copied the default **WinDriver.kext** extension to **/System/Library/Extensions**, you can install the driver by running `$ sudo <path to wdreg> WinDriver`

When distributing your driver, take care not to overwrite a newer version of **WinDriver.kext** with an older version. You should configure your installation program (if you are using one) so that the installer automatically compares the time stamp on the kernel extension folders, and does not overwrite a newer version with an older one.

2. **Install your Kernel PlugIn driver**: If you have created a Kernel PlugIn driver, install its kernel extension in the same way that you installed the WinDriver kernel extension in Step a – just replace references to the WinDriver kernel extension in this step with your Kernel PlugIn extension.

3. **Install the WinDriver API framework:** Copy **WDAPI.framework** to the **/Library/Frameworks** folder on the target machine.

4. **Install your hardware control application/framework**: Copy your hardware-control application to the target's **/Applications** folder, or copy your hardware-control framwork to the target's **/Library/Frameworks** folder, and run the application/framwork.

© Jungo Ltd. 2005–2011

14.5. Linux Driver Distribution

- The Linux kernel is continuously under development and kernel data structures are subject to frequent changes. To support such a dynamic development environment and still have kernel stability, the Linux kernel developers decided that kernel modules must be compiled with header files identical to those with which the kernel itself was compiled. They enforce this by including a version number in the kernel header files that is checked against the version number encoded into the kernel. This forces Linux driver developers to facilitate recompilation of their driver based on the target system's kernel version.

- If you have renamed the WinDriver driver module (**windrvr6.o/.ko**), as explained in Section 15.2, replace **windrvr6** references with your new driver name, and replace references to the WinDriver **redist**, **lib** and **include** directories with the path to your copy of the relevant directory. For example, when using the generated DriverWizard renamed driver files for your driver project, as explained in Section 15.2.3, you can replace references to the **WinDriver/redist** directory with references to the generated **xxx_installation/redist** directory (where **xxx** is the name of your generated driver project).

- If you wish to distribute drivers for both 32-bit and 64-bit target platforms, you must prepare a separate driver installation package for each platform. The required files for each package are located within the WinDriver installation directory for the respective platform.

14.5.1. Kernel Modules

Since (**windrvr6.o/.ko**) is a kernel module, it must be recompiled for every kernel version on which it is loaded. To enable recompilation, the following components must be distributed along with your driver source/object code.

The components are provided under the **WinDriver/redist** directory, unless otherwise specified.

- **windrvr_gcc_v2.a**, **windrvr_gcc_v3.a** and **windrvr_gcc_v3_regparm.a**: compiled object code for the WinDriver kernel module. **windrvr_gcc_v2.a** is used for kernels compiled with GCC v2.x.x, and **windrvr_gcc_v3.a** is used for kernels compiled with GCC v3.x.x. **windrvr_gcc_v3_regparm.a** is used for kernels compiled with GCC v3.x.x with the **regparm** flag.

- **linux_wrappers.c/h**: wrapper library source code files that bind the WinDriver kernel module to the Linux kernel.

- **linux_common.h**, **windrvr.h**, **wd_ver.h**, **windrvr_usb.h**, and **wdusb_interface.h**: header files required for building the WinDriver kernel module on the target.
  Note that **windrvr_usb.h** and **wdusb_interface.h** are required even for non-USB drivers.

© Jungo Ltd. 2005–2011

windrvr.h, **wd_ver.h**, and **windrvr_usb.h** are provided under the **WinDriver/include** directory.

- **configure**: a configuration script that creates **makefile** from **makefile.in** and runs **configure.wd** (see below).

If the Linux kernel version is 2.6.26 or higher, **configure** generates makefiles that use **`kbuild`** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by passing the **`--enable-kbuild`** flag to **configure**. The files that use **`kbuild`** include **.kbuild** in their names.

When you configure WinDriver for compilation, be sure to exclude USB support:

```
./configure --disable-usb-support
```

- **configure.wd**: a configuration script that creates **makefile.wd[.kbuild]** from **makefile.wd[.kbuild].in**.
- **makefile.in**: a template for the main WinDriver makefile, which compiles and installs WinDriver by making **makefile.wd[.kbuild]** .
- **makefile.wd.in**: a template for a makefile that compiles and installs the main WinDriver kernel module.
- **makefile.wd.kbuild.in**: a template for a makefile that compiles the main WinDriver kernel module using **`kbuild`**, and then installs the module.
- **setup_inst_dir**: a script to install your driver module.
- **wdreg** (provided under the **WinDriver/util** directory): a script to load the WinDriver kernel driver module (see Section 13.4).
  Note: The **setup_inst_dir** script uses **wdreg** to load the driver module.

14.5.2. User-Mode Hardware Control Application/ Shared Objects

Copy the hardware control application/shared object that you created with WinDriver to the target.

If your hardware control application/shared object uses **libwdapi1040.so** (as is the case for the sample and generated DriverWizard WinDriver projects), copy this file from the **WinDriver/lib** directory on the development machine to the target's library directory – **/usr/lib** for 32-bit x86 or 32-bit PowerPC targets, or **/usr/lib64** for 64-bit x86 targets.
If you are distributing a 32-bit application/shared object to a target 64-bit platform [A.2] – copy **libwdapi1040_32.so** from the **WinDriver/lib** directory to your distribution package, rename the copy to **libwdapi1040.so**, and copy the renamed file to the target's **/usr/lib** directory.

Since your hardware control application/shared object does not have to be matched against the kernel version number, you are free to distribute it as binary code (if you wish to protect your source code from unauthorized copying) or as source code. Note that under the license agreement with Jungo you may not distribute the source code of the **libwdapi1040.so** shared object.

If you select to distribute your source code, make sure you do not distribute your WinDriver license string, which is used in the code.

14.5.3. Kernel PlugIn Modules

This section lists the components that must be distributed together with your driver source/object code, to enable recompilation of a Kernel PlugIn module (**kp_xxx_module.o/.ko**).

Kernel PlugIn modules must be recompiled for every kernel version on which they are to be loaded. Therefore, you must supply the various Kernel PlugIn component files to your customers so that they can recompile the Kernel PlugIn. You can use the **`configure.kp`** script that DriverWizard created for you, during generation of the Kernel PlugIn, to build Kernel PlugIn modules for distribution.

You may need to modify the **configure.kp** script – especially the file paths in it.

When building the Kernel PlugIn (using the **`make`** command [12.7.3]), before distribution, the object code for the WinDriver Kernel PlugIn module is created in the **LINUX.<KERNEL_VER>.<CPU>** directory. A different type of ***.a** file is generated, depending upon the gcc version used for its compilation. For building the Kernel PlugIn on the target machine, the **.a** file type must be compatible with the target kernel:

- **kp_xxx_gcc_v2.a** is compatible with kernels compiled using GCC v2.x.x.
- **kp_xxx_gcc_v3.a** is compatible with kernels compiled using GCC v3.x.x.
- **kp_xxx_gcc_v3_regparm.a** is compatible with kernels compiled using GCC v3.x.x, with the **regparm** flag set.

It is recommended to generate and distribute all of the types of **.a** object code files, to ensure compatibility with various target environments.

Copy the Kernel PlugIn ***.a** object files from the **LINUX.<KERNEL_VER>.<CPU>** directory to the **WinDriver/lib** directory, for distribution.

The following components, generated by DriverWizard, are provided in the **WinDriver/redist** directory:

- **configure.kp**: a configuration script that creates **makefile.kp** from **makefile.[kbuild].in**.

- If the Linux kernel version is 2.6.26 or higher, **configure** generates makefiles that use **`kbuild`** to compile the kernel modules. You can force the use of **kbuild** on earlier versions of Linux, by passing the **`--enable-kbuild`** flag to **configure**.
- In general, the files for use with **`kbuild`** include **.kbuild** in their names. However, the output file **makefile.kp** is an exception to this rule.
- If you have renamed the WinDriver kernel module, be sure to uncomment the **ADDITIONAL_FLAGS** line in each of the configuration scripts.

- **makefile.kp.in**: a template for a makefile that compiles the Kernel PlugIn module and installs it.
- **makefile.kp.kbuild.in**: a template for a makefile that compiles the Kernel PlugIn module using **`kbuild`**, and then installs the module.

The following components, generated by DriverWizard, are provided in the **WinDriver/lib** directory:

- **kp_wdapi1040_gcc_v2.a**
- **kp_wdapi1040_gcc_v3.a**
- **kp_wdapi1040_gcc_v3_regparm.a**

The following components are provided in the **WinDriver/redist** directory:

- **linux_wrappers.c/h**: wrapper library source code files that bind the WinDriver kernel module to the Linux kernel.

These files must be in the same directory as **configure.kp** configuration script and the generated **makefile.kp** file. If the files are moved, modify the configuration script to refer to their new location.

- Header files required for recompiling the WinDriver kernel module on the target platform: **linux_common.h** and **wdusb_interface.h**.
  Note that **wdusb_interface.h** is required, even for non-USB drivers.

The following components are provided in the **WinDriver/include** directory:

- Header files required for recompiling the WinDriver kernel module on the target platform: **windrvr.h**, **wd_ver.h**, and **windrvr_usb.h**.
  Note that **wdusb_interface.h** is required, even for non-USB drivers.

© Jungo Ltd. 2005–2011

14.5.3.1. Rebuilding the Kernel PlugIn

Distribute the Kernel PlugIn components to the target machine and then build the Kernel PlugIn module there. For example, run the following commands on the target machine, from the **redist** directory:

To generate the Kernel PlugIn makefile:

```
$ ./configure.kp --disable-usb-support
```

To build the Kernel PlugIn module:

```
$ make -f makefile.kp
```

A **LINUX.<KERNEL_VER>.<CPU>.KP** directory is created, containing the newly compiled module: **kp_xxx_module.o/.ko**.

When using **kbuild**, make sure that there is a copy of the **Module.symvers** file in the same directory as the **configure.kp** script and the generated **makefile.kp** file. **Module.symvers** is generated during compilation of the WinDriver kernel module.

To install the Kernel PlugIn module:

```
# make install -f makefile.kp
```

Installation of a Kernel PlugIn must be performed with super user (root) privileges.

14.5.4. Installation Script

We suggest that you supply an installation shell script to automate the build and installation processes on the target.

Chapter 15
Driver Installation – Advanced Issues

15.1. Windows INF Files

Device information (INF) files are text files that provide information used by the Plug-and-Play mechanism on Windows 7 / Vista / Server 2008 / Server 2003 / XP / 2000 / Me / 98 to install software that supports a given hardware device. INF files are required for hardware that identifies itself, such as USB and PCI. An INF file includes all necessary information about a device and the files to be installed. When hardware manufacturers introduce new products, they must create INF files to explicitly define the resources and files required for each class of device.

In some cases, the INF file for your specific device is supplied by the operating system. In other cases, you will need to create an INF file for your device. WinDriver's DriverWizard can generate a specific INF file for your device. The INF file is used to notify the operating system that WinDriver now handles the selected device.

You can use DriverWizard to generate the INF file on the development machine – as explained in Section 4.2 of the manual – and then install the INF file on any machine to which you distribute the driver, as explained in the following sections.

15.1.1. Why Should I Create an INF File?

- To bind the WinDriver kernel module to a specific PCI/PCMCIA device.
- To override the existing driver (if any).
- To enable WinDriver applications and DriverWizard to access a PCI/PCMCIA device.
- To enable WinDriver to obtain a Plug-and-Play representation of PCI/PCMCIA device resources (I/O ranges, memory ranges, and interrupts).

Handling of Message-Signaled Interrupts (MSI) or Extended Message-Signaled Interrupts (MSI-X) requires specific configuration of the INF file – see further details in Section 9.2.6.1.

15.1.2. How Do I Install an INF File When No Driver Exists?

You must have administrative privileges in order to install an INF file.

You can use the **wdreg** utility with the **`install`** command to automatically install the INF file:
`wdreg -inf <path to the INF file> install`
(For more information, refer to Section 13.2.2 of the manual.)

On the development PC, you can have the INF file automatically installed when selecting to generate the INF file with DriverWizard, by checking the **Automatically Install the INF file** option in the DriverWizard's INF generation window (refer to Section 4.2).

It is also possible to install the INF file manually, using either of the following methods:

- Windows **Found New Hardware Wizard**: This wizard is activated when the device is plugged in or, if the device was already connected, when scanning for hardware changes from the Device Manager.
- Windows **Add/Remove Hardware Wizard**: Right-click the mouse on **My Computer**, select **Properties**, choose the **Hardware** tab and click on **Hardware Wizard...**.
- Windows **Upgrade Device Driver Wizard**: Locate the device in the **Device Manager** devices list and select the **Update Driver...** option from the right-click mouse menu or from the Device Manager's **Action** menu.

In all the manual installation methods above you will need to point Windows to the location of the relevant INF file during the installation.
We recommend using the **wdreg** utility to install the INF file automatically, instead of installing it manually.

If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

15.1.3. How Do I Replace an Existing Driver Using the INF File?

You must have administrative privileges in order to replace a driver.

1. Install your INF file.

You can use the **wdreg** utility with the **`install`** command to automatically install the INF file:
`wdreg -inf <path to INF file> install`
(For more information, refer to Section 13.2.2 of the manual.)

On the development PC, you can have the INF file automatically installed when selecting to generate the INF file with DriverWizard, by checking the **Automatically Install the INF file** option in the DriverWizard's INF generation window (refer to Section 4.2).

It is also possible to install the INF file manually, using either of the following methods:

- Windows **Found New Hardware Wizard**: This wizard is activated when the device is plugged in or, if the device was already connected, when scanning for hardware changes from the Device Manager.

- Windows **Add/Remove Hardware Wizard**: Right-click on **My Computer**, select **Properties**, choose the **Hardware** tab and click on **Hardware Wizard...**.

- Windows **Upgrade Device Driver Wizard**: Locate the device in the **Device Manager** devices list and select the **Update Driver...** option from the right-click mouse menu or from the Device Manager's **Action** menu.

In the manual installation methods above you will need to point Windows to the location of the relevant INF file during the installation. If the installation wizard offers to install an INF file other than the one you have generated, select **Install one of the other drivers** and choose your specific INF file from the list.

We recommend using the **wdreg** utility to install the INF file automatically, instead of installing it manually.

If the installation fails with an **`ERROR_FILE_NOT_FOUND`** error, inspect the Windows registry to see if the **`RunOnce`** key exists in **`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion`**. This registry key is required by Windows Plug-and-Play in order to properly install drivers using INF files. If the **`RunOnce`** key is missing, create it; then try installing the INF file again.

15.2. Renaming the WinDriver Kernel Driver

The WinDriver APIs are implemented within the WinDriver kernel driver module (**windrvr6.sys/.dll/.o/.ko** or **WinDriver.kext** – depending on the OS), which provides the main driver functionality and enables you to code your specific driver logic from the user mode [1.6].

On Windows, Mac OS X, and Linux you can change the name of the WinDriver kernel module to your preferred driver name, and then distribute the renamed driver instead of default kernel module – **windrvr6.sys/.o/.ko** or **WinDriver.kext**. The following sections explain how to rename the driver for each of the supported operating systems.

A renamed WinDriver kernel driver can be installed on the same machine as the original kernel module.
You can also install multiple renamed WinDriver drivers on the same machine, simultaneously.

Try to give your driver a unique name in order to avoid a potenial conflict with other drivers on the target machine on which your driver will be installed.

15.2.1. Windows Driver Renaming

DriverWizard automates most of the work of renaming the Windows WinDriver kernel driver – **windrvr6.sys**.

- When renaming the driver, the CPU architecture (32-/64-bit) of the development platform and its WinDriver installation, should match the target platform.
- Renaming the signed **windrvr6.sys** driver nullifies its signature. In such cases you can select either to sign your new driver, or to distribute an unsigned driver. For more information on driver signing and certification, refer to Section 15.3. For guidelines for signing and certifying your renamed driver, refer to Section 15.3.2.

References to **xxx** in this section should be replaced with the name of your generated DriverWizard driver project.

To rename your Windows WinDriver kernel driver, follow these steps:

1. Use the DriverWizard utility to generate driver code for your hardware on Windows (refer to Section 4.2, Step 6), using your preferred driver name (**xxx**) as the name of the generated driver project. The generated project directory (**xxx**) will include an **xxx_installation** directory with the following files and directories:
   - **redist** directory:
     - **xxx.sys** – Your new driver, which is actually a renamed copy of the **windrvr6.sys** driver. Note: The properties of the generated driver file (such as the file's version, company name, etc.) are identical to the properties of the original **windrvr6.sys** driver. You can rebuild the driver with new properties using the files from the generated **xxx_installation sys** directory, as explained below.
     - **xxx_driver.inf** – A modified version of the **windrvr6.inf** file, which will be used to install your new **xxx.sys** driver.
       You can make additional modifications to this file, if you wish – namely, changing the string definitions and/or comments in the file.
     - **xxx_device.inf** – A modified version of the standard generated DriverWizard INF file for your device, which registers your device with your driver (**xxx.sys**).
       You can make additional modifications to this file, if you wish, such as changing the manufacturer or driver provider strings.

- **wdapi1040.dll** – A copy of the WinDriver API DLL. The DLL is copied here in order to simplify the driver distribution, allowing you to use the generated **xxx\redist** directory as the main installation directory for your driver, instead of the original **WinDriver\redist** directory.

- **wdreg.exe**, **wdreg_gui.exe**, and **difxapi.dll** – Copies of the CUI and GUI versions of the **wdreg** WinDriver driver installation utility, and the Driver Install Frameworks API (**DIFxAPI**) DLL required by this utility [13.2.2], (respectively). These files are copied from the **WinDriver\util** directory, to simplify the installation of the renamed driver.

- **xxx_install.bat** – An installation script that executes the **wdreg** commands for installing the **xxx_driver.inf** and **xxx_device.inf** files. This script is designed to simplify the installation of the renamed **xxx_driver.sys** driver, and the registration of your device with this driver.

- **sys** directory: This directory contains files for advanced users, who wish to change the properties of their driver file. Note: Changing the file's properties requires rebuilding of the driver module using the Windows Driver Kit (**WDK**).
  To modify the properties of your **xxx.sys** driver file:

  1. Verify that the WDK is installed on your development PC, or elsewhere on its network, and set the **BASEDIR** environment variable to point to the WDK installation directory.

  2. Modify the **xxx.rc** resources file in the generated **sys** directory in order to set different driver file properties.

  3. Rebuild the driver by running the following command:
     `ddk_make <OS> <build mode (free/checked)>`
     For example, to build a release version of the driver for Windows XP:
     `ddk_make winxp free`

     - The selected build OS must match the CPU architecture of your WinDriver installation. For example, you cannot select the 64-bit `win7_x64` OS flag when using a 32-bit WinDriver installation.

     - The **ddk_make.bat** utility is provided under the **WinDriver\util** directory, and should be automatically identified by Windows when running the installation command.

     - Run **`ddk_make.bat`** with no parameters to view the available options for this utility.

  After rebuilding the **xxx.sys** driver, copy the new driver file to the generated **xxx_installation\redist** directory.

2. Verify that your user-mode application calls the `WD_DriverName()` function [B.1] with your new driver name before calling any other WinDriver function.
   Note that the sample and generated DriverWizard WinDriver applications already include a call to this function, but with the default driver name (**windrvr6**), so all you need to do is replace the driver name that is passed to the function in the code with your new driver name.

3. Verify that your user-mode driver project is built with the `WD_DRIVER_NAME_CHANGE` preprocessor flag (e.g., `-DWD_DRIVER_NAME_CHANGE`).
   Note: The sample and generated DriverWizard WinDriver kernel projects/makefiles already set this preprocessor flag by default.

4. Install your new driver by following the instructions in Section 14.2 of the manual, using the modified files from the generated **xxx_installation** directory instead of the installation files from the original WinDriver distribution. Note that you can use the generated **xxx_install.bat** installation script (see Step 1) to simplify the installation.

15.2.2. Mac OS X Driver Renaming

DriverWizard automates most of the work of renaming the Mac OS X WinDriver kernel driver – **WinDriver.kext**.

References to **xxx** in this section should be replaced with the name of your generated DriverWizard driver project.

To rename your Mac OS X WinDriver kernel driver, follow these steps:

1. Use the DriverWizard utility to generate driver code for your hardware on Mac OS X (refer to Section 4.2, Step 6), using your preferred driver name (**xxx**) as the name of the generated driver project. The generated project directory (**xxx**) will include an **xxx_installation** directory with the following files and directories:

   - **redist** directory: This directory contains a copy of the WinDriver API framework – **WDAPI.framework** – from the original **~/WinDriver/redist** installation directory.

   - **kernel_driver** directory: This directory contains the files required for rebuilding the renamed WinDriver kernel extension. The directory contains the following files and directories:

     - **lib** directory – which includes a **libwindriver_lib.a** archive

     - **macos** directory – which includes

       - An **xxx.xcodeproj** directory with the generared Xcode project

       - **Info.plist** and **InfoPlist.strings** files

     - Header and source files for building the renamed driver class

2. Build the renamed driver: Open the generated **xxx_installation/macos/xxx.xcodeproj** project file with Xcode, and build the code. This will create a new **xxx.kext** kernel extension at **xxx_installation/macos/build/Release** or **xxx_installation/macos/build/Debug** – depending on how you selected to perform the build.

   After creating the **xxx.kext** driver, copy it to the generated **xxx_installation/redist** directory.

3. Verify that your user-mode application calls the `WD_DriverName()` function [B.1] with your new driver name before calling any other WinDriver function.
   Note that the sample and generated DriverWizard WinDriver applications already include a call to this function, but with the default driver name (**WinDriver**), so all you need to do is replace the driver name that is passed to the function in the code with your new driver name.

4. Verify that your user-mode driver project is built with the `WD_DRIVER_NAME_CHANGE` preprocessor flag (`-DWD_DRIVER_NAME_CHANGE`).
   Note: The sample and generated DriverWizard WinDriver kernel projects/makefiles already set this preprocessor flag by default.

5. Install your new driver by following the instructions in Section 14.4 of the manual, using the modified files from the generated **xxx_installation** directory instead of the installation files from the original WinDriver distribution.

15.2.3. Linux Driver Renaming

DriverWizard automates most of the work of renaming the Linux WinDriver kernel driver – **windrvr6.o/.ko**.

References to **xxx** in this section should be replaced with the name of your generated DriverWizard driver project.

To rename your Linux WinDriver kernel driver, follow these steps:

1. Use the DriverWizard utility to generate driver code for your hardware on Linux (refer to Section 4.2, Step 6), using your preferred driver name (**xxx**) as the name of the generated driver project. The generated project directory (**xxx**) will include an **xxx_installation** directory with the following files and directories:

   - **redist** directory: This directory contains copies of the files from the original **WinDriver/redist** installation directory, but with the required modifications for building your **xxx.o/.ko** driver instead of **windrvr6.o/.ko**.

   - **lib** and **include** directories: Copies of the library and include directories from the original WinDriver distribution. These copies are created since the supported Linux WinDriver kernel driver build method relies on the existence of these directories directly under the same parent directory as the **redist** directory.

2. Verify that your user-mode application calls the `WD_DriverName()` function [B.1] with your new driver name before calling any other WinDriver function.
   Note that the sample and generated DriverWizard WinDriver applications already include a call to this function, but with the default driver name (**windrvr6**), so all you need to do is replace the driver name that is passed to the function in the code with your new driver name.

3. Verify that your user-mode driver project is built with the `WD_DRIVER_NAME_CHANGE` preprocessor flag (`-DWD_DRIVER_NAME_CHANGE`).
   Note: The sample and generated DriverWizard WinDriver kernel projects/makefiles already set this preprocessor flag by default.

4. Install your new driver by following the instructions in Section 14.5 of the manual, using the modified files from the generated **xxx_installation** directory instead of the installation files from the original WinDriver distribution.
   As part of the installation, build your new kernel driver module(s) by following the instructions in Section 14.5.1, using the files from your new installation directory.

15.3. Digital Driver Signing and Certification – Windows 7/Vista/Server 2008/Server 2003/XP

15.3.1. Overview

Before distributing your driver, you can digitally sign and/or certify it, either by submitting it to the Microsoft Windows Logo Program, for certification and signature, or by having the driver Authenticode signed.

Some Windows operating systems, such as Windows XP and below, do not require installed drivers to be digitally signed or certified. There are, however, advantages to getting your driver digitally signed or fully certified, including the following:

- Driver installation on systems where installing unsigned drivers has been blocked
- Avoiding warnings during driver installation
- Full pre-installation of INF files [15.1] on Windows XP and higher

64-bit versions of Windows Vista and higher require Kernel-Mode Code Signing (KMCS) of software that loads in kernel mode. This has the following implications for WinDriver-based drivers:

- Drivers that are installed via an INF file must be distributed together with a signed catalog file (see details in Section 15.3.2).
- Drivers that are not installed using an INF file – namely, Kernel PlugIn drivers – must contain an embedded driver signature.

For more information about digital driver signing and certification, see

- Driver Signing Requirements for Windows:
  http://www.microsoft.com/whdc/winlogo/drvsign/drvsign.mspx.

- The *Introduction to Code Signing* topic in the Microsoft Development Network (MSDN) documentation.

- Digital Signatures for Kernel Modules on Systems Running Windows Vista and higher:
  http://www.microsoft.com/whdc/winlogo/drvsign/kmsigning.mspx.
  This white paper contains information about kernel-mode code signing, test signing, and disabling signature enforcement during development.

15.3.1.1. Authenticode Driver Signature

The Microsoft Authenticode mechanism verifies the authenticity of driver's provider. It allows driver developers to include information about themselves and their code with their programs through the use of digital signatures, and informs users of the driver that the driver's publisher is participating in an infrastructure of trusted entities.
The Authenticode signature does not, however, guarantee the code's safety or functionality.

The **WinDriver\redist\windrvr6.sys** driver has an Authenticode digital signature.

15.3.1.2. WHQL Driver Certification

Microsoft's Windows Logo Program – http://www.microsoft.com/whdc/winlogo/default.mspx – lays out procedures for submitting hardware and software modules, including drivers, for Microsoft quality assurance tests. Passing the tests qualifies the hardware/software for Microsoft certification, which verifies both the driver provider's authenticity and the driver's safety and functionality.

Device drivers should be submitted for certification together with the hardware that they drive. The driver and hardware are submitted to Microsoft's Windows Hardware Quality Labs (**WHQL**) testing in order to receive digital signature and certification. This procedure verifies both the driver's provider and its behavior.

Jungo's professional services unit provides a complete WHQL pre-certification service for Jungo-based drivers. Professional engineers efficiently perform all the required tests in the Jungo WHQL test lab, relieving customers of the expense and stress of in-house testing. Jungo prepares a WHQL submission package containing the test results, and delivers the package to the customer, ready for submission to Microsoft.
For more information, refer to http://www.jungo.com/st/whql_certification.html.

For detailed information regarding the WHQL certification process, refer to the following Microsoft web pages:

- WHQL home page:
  http://www.microsoft.com/whdc/whql/default.mspx

- WHQL Policies page:
  http://www.microsoft.com/whdc/whql/policies/default.mspx

- Windows Quality Online Services (**Winqual**) home page:
  https://winqual.microsoft.com/
- Winqual help:
  https://winqual.microsoft.com/Help/
- WHQL tests, procedures and forms download page:
  http://www.microsoft.com/whdc/whql/WHQLdwn.mspx
- Windows Driver Kit (**WDK**):
  http://www.microsoft.com/whdc/devtools/wdk/default.mspx
- Driver Test Manager (**DTM**):
  http://www.microsoft.com/whdc/DevTools/WDK/DTM.mspx

Note: Some of the links require Windows Internet Explorer.

15.3.2. Driver Signing and Certification of WinDriver-Based Drivers

As indicated above [15.3.1.1], The **WinDriver\redist\windrvr6.sys** driver has an Authenticode signature. Since WinDriver's kernel module (**windrvr6.sys**) is a generic driver, which can be used as a driver for different types of hardware devices, it cannot be submitted as a standalone driver for WHQL certification. However, once you have used WinDriver to develop a Windows 7 / Vista / Server 2008 / Server 2003 / XP driver for your selected hardware, you can submit both the hardware and driver for Microsoft WHQL certification, as explained below.

The driver certification and signature procedures – either via Authenticode or WHQL – require the creation of a catalog file for the driver. This file is a sort of hash, which describes other files. The signed **windrvr6.sys** driver is provided with a matching catalog file – **WinDriver\redist\wd1040.cat**. This file is assigned to the `CatalogFile` entry in the **windrvr6.inf** file (provided as well in the **redist** directory). This entry is used to inform Windows of the driver's signature and the relevant catalog file during the driver's installation.

When the name, contents, or even the date of the files described in a driver's catalog file is modified, the catalog file, and consequently the driver signature associated with it, become invalid. Therefore, if you select to rename the **windrvr6.sys** driver [15.2] and/or the related **windrvr6.inf** file, the **wd1040.cat** catalog file and the related driver signature will become invalid.

In addition, when using WinDriver to develop a driver for your Plug-and-Play device, you normally also create a device-specific INF file that registers your device to work with the **windrvr6.sys** driver module (or a renamed version of this driver). Since this INF file is created at your site, for your specific hardware, it is not referenced from the **wd1040.cat** catalog file and cannot be signed by Jungo a priori.

When renaming **windrvr6.sys** and/or creating a device-specific INF file for your device, you have two alternative options regarding your driver's digital signing:

- Do not digitally sign your driver. If you select this option, remove or comment-out the reference to the **wd1040.cat** file from the **windrvr6.inf** file (or your renamed version of this file).

- Submit your driver for WHQL certification or have it Authenticode signed.
  Note that while renaming **WinDriver\redist\windrvr6.sys** nullifies the driver's digital signature, the driver is still WHQL-compliant and can therefore be submitted for WHQL testing.

  To digitally sign/certify your driver, follow these steps:

  - Create a new catalog file for your driver, as explained in Microsoft's WHQL documentation. The new file should reference both **windrvr6.sys** (or your renamed driver) and any INF files used in your driver's installation.

  - Assign the name of your new catalog file to the `CatalogFile` entry in your driver's INF file(s). (You can either change the `CatalogFile` entry in the **windrvr6.inf** file to refer to your new catalog file, and add a similar entry in your device-specific INF file; or incorporate both **windrvr6.inf** and your device INF file into a single INF file that contains such a `CatalogFile` entry).

  - If you wish to submit your driver for WHQL certification, refer to the additional guidelines in Section 15.3.2.1.

  - Submit your driver for WHQL certification or for an Authenticode signature.

    Note that many WinDriver customers have already successfully digitally signed and certified their WinDriver-based drivers.

15.3.2.1. WHQL DTM Test Notes

As indicated in the WHQL documentation, before submitting the driver for testing you need to download Microsoft's Driver Test Manager (**DTM**) (http://www.microsoft.com/whdc/DevTools/WDK/DTM.mspx) and run the relevant tests for your hardware/software. After you have verified that you can successfully pass the DTM tests, create the required logs package and proceed according to Microsoft's documentation.

When running the DTM tests, note the following:

- The DTM test class for WinDriver-based drivers should be **Unclassified – Universal Device**.

- The Driver Verifier test is applied to all unsigned drivers found on the test machine. It is therefore important to try and minimize the number of unsigned drivers installed on the test PC (apart from the test driver – **windrvr6.sys**).

- The ACPI Stress test requires that the ACPI settings in the BIOS support the S3 power state.

- Verify that the `/PAE` switch is added to the boot flags in the PC's **boot.ini** file.

© Jungo Ltd. 2005–2011

- Before submitting the file for certification you need to create a new catalog file, which lists your driver and specific INF file(s), and refer to this catalog file from your INF file(s), as explained above [15.3.2].

15.4. Windows XP Embedded WinDriver Component

When creating a Windows XP Embedded image using the Target Designer tool from Microsoft's Windows Embedded Studio, you can select the components that you wish to add to your image. The added components will be installed automatically during the first boot on the Windows XP Embedded target on which the image is loaded.

To automatically install the required WinDriver files – such as the **windrvr6.inf** file and the WinDriver kernel driver that it installs (**windrvr6.sys**), your device INF file (for a Plug-and-Play device – PCI/PCMCIA), and the WinDriver API DLL (**wdapi1040.dll**) – on Windows XP Embedded platforms, you can create a relevant WinDriver component and add it to your Windows XP Embedded image.
WinDriver simplifies this task for you by providing you with a ready-made component: **WinDriver\redist\xp_embedded\wd_component\windriver.sld**.
To use the provided component, follow the steps below.

The provided **windriver.sld** component relies on the existence of a **wd_files** directory in the same directory that holds the component. Therefore, do not rename the provided **WinDriver\redist\xp_embedded\wd_component\wd_files** directory or modify its contents, unless instructed to so in the following guidelines.

1. **For a Plug-and-Play device (PCI/PCMCIA) – modify the dev.inf file:**
   The **windriver.sld** component depends on the existence of a **dev.inf** file in the **wd_files** directory. The WinDriver installation on your development Windows platform contains a generic **WinDriver\redist\xp_embedded\wd_component\wd_files\dev.inf** file. Use either of the following methods to modify this file to suit your device:

   - Modify the generic **dev.inf** file to describe your device. At the very least, you must modify the template `[DeviceList]` entry and insert your device's hardware type and vendor and product IDs. For example, for a PCI device with vendor ID 0x1111 and product ID 0x2222:
     ```
     "my_dev_pci"=Install, PCI\VEN_1111\&DEV_2222
     ```

   OR:

   - Create an INF file for your device using DriverWizard (refer to Section 4.2, Step 3) and name it **dev.inf**, or use an INF file from one of WinDriver's enhanced-support chipsets [7] that suits your card and rename it to **dev.inf**. Then copy your **dev.inf** device INF file to the **WinDriver\redist\xp_embedded\wd_component\wd_files** directory.

- **For a non-Plug-and-Play (ISA) device – remove the dev.inf installation from the WinDriver component:** Remove or comment-out the following line in the installation file **WinDriver\redist\xp_embedded\wd_component\wd_files\wd_install.bat** (to comment-out the line, add two colons – :: – at the beginning of the line): `wdreg -inf dev.inf install`

2. **Add the WinDriver component to the Windows Embedded Component Database:**

    1. Open the Windows Embedded Component Database Manager (DBMgr).

    2. Click **Import**.

    3. Select the WinDriver component – **WinDriver\redist\xp_embedded\wd_component\windriver.sld** – as the SLD file and click **Import**.

3. **Add the WinDriver component to your Windows XP Embedded image:**

    1. Open your project in the Target Designer.

    2. Double-click the WinDriver component to add it to your project.
    Note: If you already have an earlier version of the WinDriver component in your project's components list, right-click this component and select **Upgrade**.

    3. Run a dependency check and build your image.

After following these steps, WinDriver will automatically be installed during the first boot on the target Windows XP Embedded platform on which your image is loaded.

If you have selected to rename the WinDriver kernel module [15.2], you will not be able to use the provided **windriver.sld** component. You can build your own component for the renamed driver, or use the **wdreg** utility to install the driver on the target Windows XP Embedded platform, as explained in the manual.

© Jungo Ltd. 2005–2011

Appendix A
64-Bit Operating Systems Support

A.1. Supported 64-Bit Architectures

WinDriver supports the following 64-bit platforms:

- Linux AMD64 or Intel EM64T (**x86_64**)
  For a full list of the Linux platforms supported by WinDriver, refer to Section 3.1.4.

- Mac OS X x86_64
  For a full list of the Mac OS X platforms supported by WinDriver, refer to Section 3.1.3.

- Windows AMD64 or Intel EM64T (**x64**).
  For a full list of the Windows platforms supported by WinDriver, refer to Section 3.1.1.

For information regarding performing 64-bit data transfers with WinDriver, including on 32-bit platforms, refer to Section 10.2.3.

A.2. Support for 32-Bit Applications on 64-Bit Windows and Linux Platforms

By default, applications created using the 64-bit versions of WinDriver are 64-bit applications. Such applications are more efficient than 32-bit applications. However, you can also use the 64-bit WinDriver versions to create 32-bit applications that will run on the supported Windows and Linux 64-bit platforms [A.1].

In the following documentation, <**WD64**> signifies the path to a 64-bit WinDriver installation directory for your target operating system, and <**WD32**> signifies the path to a 32-bit WinDriver installation directory for the same operating system.

To create a 32-bit application for 64-bit Windows or Linux platforms, using the 64-bit version of WinDriver, do the following:

1. Create a WinDriver application, as outlined in this manual (e.g., by generating code with DriverWizard, or using one of the WinDriver samples).

2. Build the application with an appropriate 32-bit compiler for your target OS, using the following configuration:

   - Add a **`KERNEL_64BIT`** preprocessor definition to your project or makefile.

In the makefiles, the definition is added using the `-D` flag: `-DKERNEL_64BIT`.

The sample and wizard-generated Linux makefiles and Windows MS Visual Studio projects, in the 64-bit WinDriver toolkit, already add this definition.

- Link the application with the specific version of the WinDriver API library/ shared object for 32-bit applications executed on 64-bit platforms – **<WD64>\lib\amd64\x86\wdapi1040.lib** on Windows **<WD64>/lib/libwdapi1040_32.so** on Linux.

  On Linux, the installation of the 64-bit WinDriver toolkit on the development machine creates a **libwdapi1040.so** symbolic link in the **/usr/lib** directory – which links to **<WD64>/lib/libwdapi1040_32.so** – and in the **/usr/lib64** directory – which links to **<WD64>/lib/libwdapi1040.so** (the 64-bit version of this shared object).
  The sample and wizard-generated WinDriver makefiles rely on these symbolic links to link with the appropriate shared object, depending on whether the code is compiled using a 32-bit or 64-bit compiler.

  On Windows, the sample and wizard-generated MS Visual Studio projects are defined to link with **wdapi1040.lib** (see the `AdditionalDependencies`), but the linker library path refers to the 64-bit library file in the **<WD64>\lib\amd64** directory (see `AdditionalLibraryDirectories`); when using such a project to compile a 32-bit application for 64-bit platforms, add **\x86** to the library path in order to link the code with **<WD64>\lib\amd64\x86\wdapi1040.lib**.

- When distributing your application to target 64-bit platforms, you need to provide with it the WinDriver API DLL/shared object for 32-bit applications executed on 64-bit platforms – **<WD64>\redist\wdapi1040_32.dll** on Windows **<WD64>/lib/ libwdapi1040_32.so** on Linux. Before distributing this file, rename the copy of the file in your distribution package by removing the **_32** portion. The installation on the target should copy the renamed DLL/shared object to the relevant OS directory – **\%windir% \sysWOW64** on Windows or **/usr/lib** on Linux. All other distribution files are the same as for any other 64-bit WinDriver driver distribution, as detailed in Chapter 14.

- An application created using the method described in this section will *not* work on 32-bit platforms. A WinDriver application for 32-bit platforms needs to be compiled without the `KERNEL_64BIT` definition; it needs to be linked with the standard 32-bit version of the WinDriver API library/shared object from the 32-bit WinDriver installation (**<WD32> \lib\x86\wdapi1040.lib** on Windows / **<WD32>/lib/libwdapi1040.so** on Linux); and it should be distributed with the standard 32-bit WinDriver API DLL/shared object (**<WD32>\redist\wdapi1040.dll** on Windows / **<WD32>/lib/libwdapi1040.so** on Linux) and any other required 32-bit distribution file, as outlined in Chapter 14.

A.3. 32-Bit and 64-Bit Support on Mac OS X

The WinDriver binaries for Mac OS X – namely, the WinDriver kernel modules (**WinDriver.kext** and your Kernel PlugIn driver [11], if created), the WDAPI framework

(**WDAPI.framework**), and the user-mode applications – are unified binaries, which can be configured in either 32-bit or 64-bit mode.

The OS loader automatically loads the kernel module and framework configuration that matches the kernel architecture of the target machine.
User-mode applications are executed, by default, as 64-bit applications. It is possible, however, to force the execution of an application in 32-bit mode, as explained below [A.3.1].

WinDriver supports execution of 32-bit applications on 32-bit or 64-bit Mac OS X platforms, and execution of of 64-bit applications on 64-bit platforms; it does not, however, support execution of 64-bit applications on 32-bit platforms. Therefore, on 32-bit Mac OS X platforms, you must execute your WinDriver applications as 32-bit applications; on 64-bit platforms, you have the choice of whether to execute your applications in 64-bit mode (default) or 32-bit mode.

A.3.1. Running 32-Bit Applications on 64-Bit Mac OS X Platforms

Mac OS X provides the **arch** utility, which enables execution of an application in 32-bit mode, thus bypassing the default 64-bit user-mode configuration [A.3].

To execute a user-mode application in 32-bit mode, you need to run the application using **arch**, in the following manner:

```
$ arch -arch <32-bit architecture> <application name>
```

For example, to execute an application named **test_app** in 32-bit mode on a 32-bit x86 Mac OS X platform, run

```
$ arch -arch i386 test_app
```

A.4. 64-Bit and 32-Bit Data Types

In general, DWORD is unsigned long. While any 32-bit compiler treats this type as 32 bits wide, 64-bit compilers treat this type differently. With Windows 64-bit compilers the size of this type is still 32 bits. However, with UNIX 64-bit compilers (e.g., GCC, SUN Forte) the size of this type is 64 bits. In order to avoid compiler dependency issues, use the UINT32 and UINT64 cross-platform types when you want to refer to a 32-bit or 64-bit address, respectively.

Appendix B
API Reference

This function reference is C oriented. The WinDriver .NET, Visual Basic and Delphi APIs have been implemented as closely as possible to the C APIs, therefore .NET, VB and Delphi programmers can also use this reference to better understand the WinDriver APIs for their selected development language. For the exact API implementation and usage examples for your selected language, refer to the WinDriver .NET/VB/Delphi source code.

B.1. WD_DriverName

Purpose

Sets the name of the WinDriver kernel module, which will be used by the calling application.

- The default driver name, which is used if the function is not called, is **windrvr6** or **WinDriver** (on Mac OS X).
- This function must be called once, and only once, from the beginning of your application, before calling any other WinDriver function (including `WD_Open`() / `WDC_DriverOpen`() / `WDC_xxxDeviceOpen`()), as demonstrated in the sample and generated DriverWizard WinDriver applications, which include a call to this function with the default driver name – **windrvr6** or **WinDriver** (on Mac OS X).
- On Windows, Mac OS X, and Linux, if you select to modify the name of the WinDriver kernel module (**windrvr6.sys/.o/.ko** or **WinDriver.kext**), as explained in Section 15.2, you must ensure that your application calls `WD_DriverName`() with your new driver name.
- In order to use the `WD_DriverName`() function, your user-mode driver project must be built with `WD_DRIVER_NAME_CHANGE` preprocessor flag (e.g.: `-DWD_DRIVER_NAME_CHANGE` – for MS Visual Studio and gcc).
  The sample and generated DriverWizard Windows, Mac OS X, and Linux WinDriver projects/ makefiles already set this preprocessor flag.

Prototype

```
const char* DLLCALLCONV WD_DriverName(const char* sName);
```

Parameters

Name	Type	Input/Output
sName	const char*	Input

Description

Name	Description
sName	The name of the WinDriver kernel module to be used by the application. NOTE: The driver name should be indicated without the driver file's extension. For example, use **windrvr6**, not **windrvr6.sys** or **windrvr6.o**.

Return Value

Returns the selected driver name on success; returns NULL on failure (e.g., if the function is called twice from the same application)long.

Remarks

The ability to rename the WinDriver kernel module is supported on Windows, Mac OS X, and Linux, as explained in Section 15.2.
On Windows CE, always call the `WD_DriverName()` function with the default WinDriver kernel module name – **windrvr6** or **WinDriver** (on Mac OS X) – or refrain from calling the function altogether.

B.2. WDC Library Overview

The *"WinDriver Card"* – **WDC** – API provides convenient user-mode wrappers to the basic WinDriver PCI/ISA/PCMCIA/CardBus `WD_xxx` API, which is described in the **WinDriver PCI Low-Level API Reference**.

The WDC wrappers are designed to simplify the usage of WinDriver for communicating with PCI/ISA/PCMCIA/CardBus devices. While you can still use the basic `WD_xxx` PCI/PCMCIA/ISA WinDriver API from your code, we recommend that you refrain from doing so and use the high-level WDC API instead.

NOTE: Most of the WDC API can be used both from the user mode and from the kernel mode (from a Kernel PlugIn driver [11]).

The generated DriverWizard PCI/PCMCIA/ISA diagnostics driver code, as well as the PLX sample code, and the **pci_diag**, Kernel PlugIn **pci_diag**, **pcmcia_diag** and **pci_dump** samples, for example, utilize the WDC API.

The WDC API is part of **wdapi1040** DLL/shared object:
WinDriver\redist\WINCE\<TARGET_CPU>\wdapi1040.dll (Windows CE) / **WinDriver/lib/libwdapi1040.so** (Linux).
The source code for the WDC API is found in the **WinDriver/src/wdapi** directory.

The WDC interface is provided in the **wdc_lib.h** and **wdc_defs.h** header files (both found under the **WinDriver/includes** directory).

- [**wdc_lib.h**] declares the "high-level" WDC API (type definitions, function declarations, etc.).
- [**wdc_defs.h**] declares the "low-level" WDC API. This file includes definitions and type information that is encapsulated by the high-level **wdc_lib.h** file.

The WinDriver PCI/PCMCIA/ISA samples and generated DriverWizard code that utilize the WDC API, for example, consist of a "library" for the specific device, and a diagnostics application that uses it. The high-level diagnostics code only utilizes the **wdc_lib.h** API, while the library code also uses the low-level API from the **wdc_defs.h** file, thus maintaining the desired level of encapsulation.

The following sections describe the WDC high-level [B.3] and low-level [B.4] API.

- PCMCIA is supported only on Windows 7/Vista/Server 2008/Server 2003/XP.
- On Mac OS X, only PCI and PCI Express are supported.
- CardBus devices are handled via WinDriver's PCI API; therefore *PCI* references in this section apply also to CardBus, on the operating systems on which it is supported [1.1].

B.3. WDC High-Level API

This section describes the WDC API defined in the **WinDriver/include/wdc_lib.h** header file.

B.3.1. Structures, Types and General Definitions

B.3.1.1. WDC_DEVICE_HANDLE

Handle to a WDC device information structure [B.4.3].

```
typedef void * WDC_DEVICE_HANDLE;
```

B.3.1.2. WDC_DRV_OPEN_OPTIONS Definitions

```
typedef DWORD WDC_DRV_OPEN_OPTIONS;
```

Preprocessor definitions of flags that describe tasks to be performed when opening a handle to the WDC library (see `WDC_DriverOpen()` [B.3.2]).

Name	Description
WDC_DRV_OPEN_CHECK_VER	Compare the version of the WinDriver source files used by the code with the version of the loaded WinDriver kernel

Name	Description
WDC_DRV_OPEN_REG_LIC	Register a WinDriver license registration string

The following preprocessor definitions provide convenient WDC driver open options, which can be passed to `WDC_DriverOpen()` [B.3.2]:

Name	Description
WDC_DRV_OPEN_BASIC	Instructs `WDC_DriverOpen()` [B.3.2] to perform only the basic WDC open tasks, mainly open a handle to WinDriver's kernel module. NOTE: The value of this option is zero (<=> no driver open flags), therefore this option cannot be combined with any of the other WDC driver open options.
WDC_DRV_OPEN_KP	Convenience option when calling `WDC_DriverOpen()` [B.3.2] from the Kernel PlugIn. This option is equivalent to setting the `WDC_DRV_OPEN_BASIC` flag, which is the recommended option to set when opening a handle to the WDC library from the Kernel PlugIn.
WDC_DRV_OPEN_ALL	A convenience mask of all the basic WDC driver open flags – `WDC_DRV_OPEN_CHECK_VER` and `WDC_DRV_OPEN_REG_REG_LIC`. (The basic functionality of opening a handle to WinDriver's kernel module is always performed by `WDC_DriverOpen()` [B.3.2], so there is no need to also set the `WDC_DRV_OPEN_BASIC` flag).
WDC_DRV_OPEN_DEFAULT	Use the default WDC open options: • For **user-mode** applications: equivalent to setting `WDC_DRV_OPEN_ALL` ; • For a **Kernel PlugIn**: equivalent to setting `WDC_DRV_OPEN_KP`

B.3.1.3. WDC_DIRECTION Enumeration

Enumeration of a device's address/register access directions.

Enum Value	Description
WDC_READ	Read from the address
WDC_WRITE	Write to the address
WDC_READ_WRITE	Read from the address or write to it. This value is used, for example, in the WinDriver samples and generated DriverWizard diagnostics code in order to describe a register's access mode, indicating that the register can either be read from or written to.

B.3.1.4. WDC_ADDR_MODE Enumeration

Enumeration of memory or I/O addresses/registers read/write modes.
The enumeration values are used to determine whether a memory or I/O address/register is read/written in multiples of 8, 16, 32 or 64 bits (i.e., 1, 2, 4 or 8 bytes).

Enum Value	Description
WDC_MODE_8	8 bits (1 byte) mode
WDC_MODE_16	16 bits (2 bytes) mode
WDC_MODE_32	32 bits (4 bytes) mode
WDC_MODE_64	64 bits (8 bytes) mode

B.3.1.5. WDC_ADDR_RW_OPTIONS Enumeration

Enumeration of flags that are used to determine how a memory or I/O address will be read/written.

Enum Value	Description
WDC_ADDR_RW_DEFAULT	Use the default read/write options: memory addresses are accessed directly from the calling process; block transfers are performed from subsequent addresses (automatic increment). NOTE: The value of this flag is zero (<=> no read/write flags), therefore it **can not** be combined in a bit-mask with any of the other read/write options flags. This option is used by the `WDC_ReadAddr8/16/32/64`() [B.3.21] and `WDC_WriteAddr8/16/32/64`() [B.3.22] functions.
WDC_ADDR_RW_NO_AUTOINC	Do no automatically increment the read/write address in block transfers, i.e., hold the device address constant while reading/writing a block of memory or I/O addresses (relevant only for block (string) transfers).

B.3.1.6. WDC_ADDR_SIZE Definitions

```
typedef DWORD WDC_ADDR_SIZE;
```

Preprocessor definitions that depict memory or I/O address/register sizes.

Name	Description
WDC_SIZE_8	8 bits (1 byte)
WDC_SIZE_16	16 bits (2 bytes)

Name	Description
WDC_SIZE_32	32 bits (4 bytes)
WDC_SIZE_64	64 bits (8 bytes)

B.3.1.7. WDC_SLEEP_OPTIONS Definitions

```
typedef DWORD WDC_SLEEP_OPTIONS;
```

Preprocessor definitions that depict the sleep options that can be passed to `WDC_Sleep`() [B.3.58].

Name	Description
WDC_SLEEP_BUSY	Delay execution, by consuming CPU cycles (busy sleep)
WDC_SLEEP_NON_BUSY	Delay execution, without consuming CPU cycles (non-busy sleep). Note: Minimum 17,000 microseconds. Less accurate than busy sleep.

B.3.1.8. WDC_DBG_OPTIONS Definitions

```
typedef DWORD WDC_DBG_OPTIONS;
```

Preprocessor definitions that depict the possible debug options for the WDC library, which are passed to `WDC_SetDebugOptions`() [B.3.52].

The following flags determine the output file for the WDC library's debug messages:

Name	Description
WDC_DBG_OUT_DBM	Send debug messages from the WDC library to the Debug Monitor [6.2]
WDC_DBG_OUT_FILE	Send debug messages from the WDC library to a debug file. By default, the debug file will be **stderr**, unless a different file is set in the **`sDbgFile`** parameter of the `WDC_SetDebugOptions`() function [B.3.52]. This option is only supported from the user mode (as opposed to the Kernel PlugIn).

The following flags determine the debug level – i.e., what type of WDC debug messages to display, if at all:

Name	Description
WDC_DBG_LEVEL_ERR	Display only WDC error debug messages
WDC_DBG_LEVEL_TRACE	Display both error and trace WDC debug messages
WDC_DBG_NONE	Do not display WDC debug messages

The following preprocessor definitions provide convenient debug flags combinations, which can be passed to `WDC_SetDebugOptions`() [B.3.52]:

• User-mode and Kernel PlugIn convenience debug options:

Name	Description
WDC_DBG_DEFAULT	`WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_TRACE`: Use the default debug options – send WDC error and trace messages to the Debug Monitor [6.2].
WDC_DBG_DBM_ERR	`WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_ERR`: Send WDC error debug messages to the Debug Monitor [6.2].
WDC_DBG_DBM_TRACE	`WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages to the Debug Monitor [6.2].
WDC_DBG_FULL	Full WDC debugging: • From the **user mode**: `WDC_DBG_OUT_DBM | WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages both to the Debug Monitor [6.2] and to a debug output file (default file: **stderr**) • From the **Kernel PlugIn**: `WDC_DBG_OUT_DBM | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace messages to the Debug Monitor [6.2]

• User-mode only convenience debug options:

Name	Description
WDC_DBG_FILE_ERR	`WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_ERR`: Send WDC error debug messages to a debug file (default file: **stderr**)
WDC_DBG_FILE_TRACE	`WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages to a debug file (default file: **stderr**)
WDC_DBG_DBM_FILE_ERR	`WDC_DBG_OUT_DBM | WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_ERR`: Send WDC error debug messages both to the Debug Monitor [6.2] and to a debug file (default file: **stderr**)
WDC_DBG_DBM_FILE_TRACE	`WDC_DBG_OUT_DBM | WDC_DBG_OUT_FILE | WDC_DBG_LEVEL_TRACE`: Send WDC error and trace debug messages both to the Debug Monitor [6.2] and to a debug file (default file: **stderr**)

B.3.1.9. WDC_SLOT_U Union

WDC PCI/PCMCIA device location information union.

Field	Type	Description
pciSlot	WD_PCI_SLOT	PCI device location information structure [B.5.8]
pcmciaSlot	WD_PCMCIA_SLOT	PCMCIA device location information structure [B.5.9]

B.3.1.10. WDC_PCI_SCAN_RESULT Structure

Structure for holding the results of a PCI bus scan (see `WDC_PciScanDevices`() [B.3.4]).

Field	Type	Description
dwNumDevices	DWORD	Number of devices found on the PCI bus that match the search criteria (vendor & device IDs)
deviceId	WD_PCI_ID[WD_PCI_CARDS]	Array of matching vendor and device IDs found on the PCI bus [B.5.6]
deviceSlot	WD_PCI_SLOT[WD_PCI_CARDS]	Array of PCI device location information structures [B.5.8] for the detected devices matching the search criteria

B.3.1.11. WDC_PCMCIA_SCAN_RESULT Structure

Structure for holding the results of a PCMCIA bus scan (see `WDC_PcmciaScanDevices`() [B.3.7]).

Field	Type	Description
dwNumDevices	DWORD	Number of devices found on the PCMCIA bus that match the search criteria (manufacturer & device IDs)
deviceId	WD_PCMCIA_ID[WD_PCMCIA_CARDS]	Array of matching vendor and device IDs found on the PCMCIA bus [B.5.7]
deviceSlot	WD_PCMCIA_SLOT[WD_PCMCIA_CARDS]	Array of PCMCIA device location

Field	Type	Description
		information structures [B.5.9] for the detected devices matching the search criteria

B.3.2. WDC_DriverOpen()

Purpose

Opens and stores a handle to WinDriver's kernel module and initializes the WDC library according to the open options passed to it.
This function should be called once before calling any other WDC API.

Prototype

```
DWORD DLLCALLCONV WDC_DriverOpen(
    WDC_DRV_OPEN_OPTIONS openOptions,
    const CHAR *sLicense);
```

Parameters

Name	Type	Input/Output
openOptions	WDC_DRV_OPEN_OPTIONS	Input
sLicense	const CHAR*	Input

Description

Name	Description
openOptions	A mask of any of the supported open flags [B.3.1.2], which determines the initialization actions that will be performed by the function.
sLicense	WinDriver license registration string. This argument is ignored if the `WDC_DRV_OPEN_REG_LIC` flag is not [B.3.1.2] set in the **`openOptions`** argument. If this parameter is a `NULL` pointer or an empty string, the function will attempt to register the demo WinDriver evaluation license. Therefore, when evaluating WinDriver pass `NULL` as this parameter. After registering your WinDriver toolkit, modify the code to pass your WinDriver license registration string.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.3. WDC_DriverClose()

Purpose

Closes the WDC WinDriver handle (acquired and stored by a previous call to `WDC_DriverOpen`() [B.3.2]) and uninitializes the WDC library.

Every `WDC_DriverOpen`() call should have a matching `WDC_DriverClose`() call, which should be issued when you no longer need to use the WDC library.

Prototype

```
DWORD DLLCALLCONV WDC_DriverClose(void);
```

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.4. WDC_PciScanDevices()

Purpose

Scans the PCI bus for all devices with the specified vendor and device ID combination and returns information regarding the matching devices that were found and their locations. The function performs the scan by iterating through all possible PCI buses on the host platform, then through all possible PCI slots, and then through all possible PCI functions.

Scan-By-Topology Note
On rare occasions, as a result of malfunctioning hardware, the scan information may contain repeated instances of the same device. As a result, the function might fail to return valid scan data. In such cases, if you cannot remove the malfunctioning device, you can scan the PCI bus using `WDC_PciScanDevicesByTopology`() [B.3.5] or `WDC_PciScanRegisteredDevices`() [B.3.6].

Linux PPC64 WDC_PciScanRegisteredDevices() Note
On Linux PPC64, `WDC_PciScanDevices`() behaves like `WDC_PciScanRegisteredDevices`() [B.3.6].

Multiple Bridges PCI Scan Note
On operating systems with multiple host bridges – such as Linux PPC – the scan function does not distinguish between PCI cards that are located on the same bus, slot, and function, but on different bridges (domains); the scan results for such devices will be identical.

Prototype

```
DWORD DLLCALLCONV WDC_PciScanDevices(
    DWORD dwVendorId,
    DWORD dwDeviceId,
    WDC_PCI_SCAN_RESULT *pPciScanResult);
```

Parameters

Name	Type	Input/Output
dwVendorId	DWORD	Input
dwDeviceId	DWORD	Input
pPciScanResult	WDC_PCI_SCAN_RESULT*	Output

Description

Name	Description
dwVendorId	Vendor ID to search for (hexadecimal). Zero (0) – all vendor IDs.
dwDeviceId	Device ID to search for (hexadecimal). Zero (0) – all device IDs.
pPciScanResult	A pointer to a structure that will be updated by the function with the results of the PCI bus scan [B.3.1.10]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- If you set both the vendor and device IDs to zero, the function will return information regarding all connected PCI devices.

B.3.5. WDC_PciScanDevicesByTopology()

Purpose

Scans the PCI bus for all devices with the specified vendor and device ID combination and returns information regarding the matching devices that were found and their locations. The function performs the scan by topology – i.e., for each located bridge the function scans the connected devices and functions reported by the bridge, and only then proceeds to scan the next bridge.

- In the case of multiple host controllers, `WDC_PciScanDevicesByTopology()` will perform the scan only for the first host controller.
- By default, use `WDC_PciScanDevices()` [B.3.4] to scan the PCI bus, unless a device malfunction intererferes – refer to the note in the description of `PciScanDevices()`.
- The Multiple Bridges PCI Scan Note, in the documentation of `WDC_PciScanDevices()` [B.3.4], applies also to `WDC_PciScanDevicesByTopology()`.

Prototype

```
DWORD DLLCALLCONV WDC_PciScanDevicesByTopology(
    DWORD dwVendorId,
    DWORD dwDeviceId,
    WDC_PCI_SCAN_RESULT *pPciScanResult);
```

Parameters

Name	Type	Input/Output
dwVendorId	DWORD	Input
dwDeviceId	DWORD	Input
pPciScanResult	WDC_PCI_SCAN_RESULT*	Output

Description

Name	Description
dwVendorId	Vendor ID to search for (hexadecimal). Zero (0) – all vendor IDs.
dwDeviceId	Device ID to search for (hexadecimal). Zero (0) – all device IDs.
pPciScanResult	A pointer to a structure that will be updated by the function with the results of the PCI bus scan [B.3.1.10]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- If you set both the vendor and device IDs to zero, the function will return information regarding all connected PCI devices.

B.3.6. WDC_PciScanRegisteredDevices()

Purpose

Scans the PCI bus for all devices with the specified vendor and device ID combination that have been registered to work with WinDriver, and returns information regarding the matching devices that were found and their locations. The function performs the scan by iterating through all possible PCI buses on the host platform, then through all possible PCI slots, and then through all possible PCI functions.

- By default, use `WDC_PciScanDevices()` [B.3.4] to scan the PCI bus, unless a device malfunction intererferes – refer to the note in the description of `PciScanDevices()`.
- The Multiple Bridges PCI Scan Note, in the documentation of `WDC_PciScanDevices()` [B.3.4], applies also to `WDC_PciScanRegisteredDevices()`.

Prototype

```
DWORD DLLCALLCONV WDC_PciScanRegisteredDevices(
    DWORD dwVendorId,
    DWORD dwDeviceId,
    WDC_PCI_SCAN_RESULT *pPciScanResult);
```

Parameters

Name	Type	Input/Output
dwVendorId	DWORD	Input
dwDeviceId	DWORD	Input
pPciScanResult	WDC_PCI_SCAN_RESULT*	Output

Description

Name	Description
dwVendorId	Vendor ID to search for (hexadecimal). Zero (0) – all vendor IDs.
dwDeviceId	Device ID to search for (hexadecimal). Zero (0) – all device IDs.
pPciScanResult	A pointer to a structure that will be updated by the function with the results of the PCI bus scan [B.3.1.10]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- If you set both the vendor and device IDs to zero, the function will return information regarding all connected PCI devices that are registered with WinDriver.

B.3.7. WDC_PcmciaScanDevices()

Purpose

Scans the PCMCIA bus for all devices with the specified manufacturer and device ID combination and returns information regarding the matching devices that were found and their locations.

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaScanDevices(
    WORD wManufacturerId,
    WORD wDeviceId,
    WDC_PCMCIA_SCAN_RESULT *pPcmciaScanResult);
```

Parameters

Name	Type	Input/Output
wManufacturerId	WORD	Input
wDeviceId	WORD	Input
pPcmciaScanResult	WDC_PCMCIA_SCAN_RESULT*	Output

Description

Name	Description
wManufacturerId	Manufacturer ID to search for (hexadecimal). Zero (0) – all manufacturer IDs.
wDeviceId	Device ID to search for (hexadecimal). Zero (0) – all device IDs.
pPcmciaScanResult	A pointer to a structure that will be updated by the function with the results of the PCMCIA bus scan [B.3.1.11]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- If you set both the vendor and device IDs to zero, the function will return information regarding all connected PCI devices.

B.3.8. WDC_PciGetDeviceInfo()

Purpose

Retrieves a PCI device's resources information (memory and I/O ranges and interrupt information).

Prototype

```
DWORD DLLCALLCONV WDC_PciGetDeviceInfo(
    WD_PCI_CARD_INFO *pDeviceInfo);
```

Parameters

Name	Type	Input/Output
pDeviceInfo	WD_PCI_CARD_INFO*	Input/Output
• pciSlot	WD_PCI_SLOT	Input
• Card	WD_CARD	Output

Description

Name	Description
pDeviceInfo	Pointer to a PCI device information structure [B.5.12]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- The resources information is obtained from the operating system's Plug-and-Play manager, unless the information is not available, in which case it is read directly from the PCI configuration registers.
  Note: On Windows, you must install an **INF file** file, which registers your device with WinDriver, before calling this function (see Section 15.1 regarding creation of INF files with WinDriver).

- If the Interrupt Request (IRQ) number is obtained from the Plug-and-Play manager, it is mapped, and therefore may differ from the physical IRQ number.

B.3.9. WDC_PcmciaGetDeviceInfo()

Purpose

Retrieves a PCMCIA device's resources information (memory and I/O ranges and interrupt information).

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaGetDeviceInfo(
    WD_PCMCIA_CARD_INFO *pDeviceInfo);
```

Parameters

Name	Type	Input/Output
pDeviceInfo	WD_PCMCIA_CARD_INFO*	Input/Output
• pcmciaSlot	WD_PCMCIA_SLOT	Input
• Card	WD_CARD	Output
• cVersion	CHAR [WD_PCMCIA_VERSION_LEN]	Output
• cManufacturer	CHAR[WD_PCMCIA_ MANUFACTURER_LEN]	Output
• cProductName	CHAR[WD_PCMCIA_ PRODUCTNAME_LEN]	Output
• wManufacturerId	WORD	Output
• wCardId	WORD	Output
• wFuncId	WORD	Output

Description

Name	Description
pDeviceInfo	Pointer to a PCMCIA device information structure [B.5.13]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- The resources information is obtained from the operating system's Plug-and-Play manager, unless the information is not available, in which case it is read directly from the PCMCIA configuration registers.
  Note: On Windows, you must install an **INF file**, which registers your device with WinDriver, before calling this function (see Section 15.1 regarding creation of INF files with WinDriver).

- If the Interrupt Request (IRQ) number is obtained from the Plug-and-Play manager, it is mapped, and therefore may differ from the physical IRQ number.

B.3.10. WDC_PciDeviceOpen()

Purpose

Allocates and initializes a WDC PCI device structure, registers the device with WinDriver, and returns a handle to the device.

This function

- Verifies that none of the registered device resources (set in **`pDeviceInfo->Card.Item`**) are already locked for exclusive use.

  A resource can be locked for exclusive use by setting the `fNotSharable` field of its `WD_ITEMS` structure [B.5.10] to 1, before calling `WDC_PciDeviceOpen`().

- Maps the physical memory ranges found on the device both to kernel-mode and user-mode address space, and stores the mapped addresses in the allocated device structure for future use.

- Saves device resources information required for supporting the communication with the device. For example, the function saves the Interrupt Request (IRQ) number and the interrupt type, as well as retrieves and saves an interrupt handle, and this information is later used when the user calls functions to handle the device's interrupts.

- If the caller selects to use a Kernel PlugIn driver to communicate with the device, the function opens a handle to this driver and stores it for future use.

Prototype

```
DWORD DLLCALLCONV WDC_PciDeviceOpen(
    WDC_DEVICE_HANDLE *phDev,
    const WD_PCI_CARD_INFO *pDeviceInfo,
    const PVOID pDevCtx,
    PVOID reserved,
    const CHAR *pcKPDriverName,
    PVOID pKPOpenData);
```

Parameters

Name	Type	Input/Output
phDev	WDC_DEVICE_HANDLE*	Output
pDeviceInfo	const WD_PCI_CARD_INFO*	Input
• pciSlot	WD_PCI_SLOT	Input
• Card	WD_CARD	Input
* dwItems	DWORD	Input
* Item	WD_ITEMS[WD_CARD_ITEMS]	Input
• item	DWORD	Input
• fNotSharable	DWORD	Input
• dwReserved	DWORD	N/A
• dwOptions	DWORD	Input
• I	union	Input
* Mem	struct	Input
• dwPhysicalAddr	DWORD	Input
• dwBytes	DWORD	Input
• dwTransAddr	DWORD	N/A
• dwUserDirectAddr	DWORD	N/A
• dwCpuPhysicalAddr	DWORD	N/A
• dwBar	DWORD	Input
* IO	struct	Input
• dwAddr	DWORD	Input
• dwBytes	DWORD	Input
• dwBar	DWORD	Input
* Int	struct	Input
• dwInterrupt	DWORD	Input
• dwOptions	DWORD	Input
• hInterrupt	DWORD	N/A
* Bus	struct	Input
• dwBusType	WD_BUS_TYPE	Input
• dwBusNum	DWORD	Input
• dwSlotFunc	DWORD	Input
* Val	struct	N/A
pDevCtx	const PVOID	Input

Name	Type	Input/Output
reserved	PVOID	
pcKPDriverName	const CHAR*	Input
pKPOpenData	PVOID	Input

Description

Name	Description
phDev	Pointer to a handle to the WDC device allocated by the function
pDeviceInfo	Pointer to a PCI device information structure [B.5.12], which contains information regarding the device to open
pDevCtx	Pointer to device context information, which will be stored in the device structure
reserved	Reserved for future use
pcKPDriverName	Kernel PlugIn driver name. Set to `NULL` when not required. This parameter is used to open a handle to a Kernel PlugIn driver together with opening a handle to the device. Note that this method cannot be used to acquire a handle to a 64-bit Kernel PlugIn driver from a 32-bit application. It is therefore recommended to open a Kernel PlugIn handle (when necessary) using `WDC_KernelPlugInOpen`() [B.3.17] (see Section 12.4).
pKPOpenData	Kernel PlugIn driver-open data to be passed to `WD_KernelPlugInOpen`() (see the **WinDriver PCI Low-Level API Reference**). This parameter is applicable only when **`pcKPDriverName`** is not `NULL`; otherwise, set it to `NULL`.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

1. This function can be called from the **user mode only**.

2. If your card has a large memory range, which cannot be mapped entirely to the kernel virtual address space, you can modify the relevant item for this resource in the card resources information structure that you received from `WDC_PciGetDeviceInfo`() [B.3.8], and set the `WD_ITEM_DO_NOT_MAP_KERNEL` flag in the item's `dwOptions` field (`pDeviceInfo->Card.Item[i].dwOptions`) before passing the information structure (`pDeviceInfo`) to `WDC_PciDeviceOpen`(). This flag instructs the function to map the relevant memory range only to the user-mode virtual address space but not the kernel address space.

NOTE that if you select to set the `WD_ITEM_DO_NOT_MAP_KERNEL` flag, the device information structure that will be created by the function will not hold a kernel-mapped address for this resource (`pAddrDesc[i].kptAddr` in the `WDC_DEVICE` structure [B.4.3] for the relevant memory range will not be updated) and you will therefore not be able to rely on this mapping in calls to WinDriver's API or when accessing the memory from a Kernel PlugIn driver.

B.3.11. WDC_PcmciaDeviceOpen()

Purpose

Allocates and initializes a WDC PCMCIA device structure, registers the device with WinDriver, and returns a handle to the device.

This function

- Verifies that none of the registered device resources (set in **`pDeviceInfo->Card.Item`**) are already locked for exclusive use.

  A resource can be locked for exclusive use by setting the `fNotSharable` field of its `WD_ITEMS` structure [B.5.10] to 1, before calling `WDC_PcmciaDeviceOpen`().

- Maps the device's physical memory ranges device both to kernel-mode and user-mode address space, and stores the mapped addresses in the allocated device structure for future use.

- Saves device resources information required for supporting the communication with the device. For example, the function saves the Interrupt Request (IRQ) number and the interrupt type, as well as retrieves and saves an interrupt handle, and this information is later used when the user calls functions to handle the device's interrupts.

- If the caller selects to use a Kernel PlugIn driver to communicate with the device, the function opens a handle to this driver and stores it for future use.

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaDeviceOpen(
    WDC_DEVICE_HANDLE *phDev,
    const WD_PCMCIA_CARD_INFO *pDeviceInfo,
    const PVOID pDevCtx,
    PVOID reserved,
    const CHAR *pcKPDriverName,
    PVOID pKPOpenData);
```

Parameters

Name	Type	Input/Output
phDev	WDC_DEVICE_HANDLE*	Output
pDeviceInfo	const WD_PCMCIA_CARD_INFO*	Input
• pcmciaSlot	WD_PCMCIA_SLOT	Input
• Card	WD_CARD	Input
* dwItems	DWORD	Input
* Item	WD_ITEMS[WD_CARD_ITEMS]	Input
• item	DWORD	Input
• fNotSharable	DWORD	Input
• dwReserved	DWORD	N/A
• dwOptions	DWORD	Input
• I	union	Input
* Mem	struct	Input
• dwPhysicalAddr	DWORD	Input
• dwBytes	DWORD	Input
• dwTransAddr	DWORD	N/A
• dwUserDirectAddr	DWORD	N/A
• dwCpuPhysicalAddr	DWORD	N/A
• dwBar	DWORD	Input
* IO	struct	Input
• dwAddr	DWORD	Input
• dwBytes	DWORD	Input
• dwBar	DWORD	Input
* Int	struct	N/A
• dwInterrupt	DWORD	Input
• dwOptions	DWORD	Input
• hInterrupt	DWORD	N/A
* Bus	struct	Input
• dwBusType	WD_BUS_TYPE	Input
• dwBusNum	DWORD	Input
• dwSlotFunc	DWORD	Input
* Val	struct	N/A
• cVersion	CHAR [WD_PCMCIA_VERSION_LEN]	Input

Name	Type	Input/Output
• cManufacturer	CHAR[WD_PCMCIA_ MANUFACTURER_LEN]	Input
• cProductName	CHAR[WD_PCMCIA_ PRODUCTNAME_LEN]	Input
• wManufacturerId	WORD	Input
• wCardId	WORD	Input
• wFuncId	WORD	Input
pDevCtx	const PVOID	Input
reserved	PVOID	
pcKPDriverName	const CHAR*	Input
pKPOpenData	PVOID	Input

Description

Name	Description
phDev	Pointer to a handle to the WDC device allocated by the function
pDeviceInfo	Pointer to a PCMCIA device information structure [B.5.13], which contains information regarding the device to open
pDevCtx	Pointer to device context information, which will be stored in the device structure
reserved	Reserved for future use
pcKPDriverName	Kernel PlugIn driver name. Set to `NULL` when not required. This parameter is used to open a handle to a Kernel PlugIn driver together with opening a handle to the device. Note that this method cannot be used to acquire a handle to a 64-bit Kernel PlugIn driver from a 32-bit application. It is therefore recommended to open a Kernel PlugIn handle (when necessary) using `WDC_KernelPlugInOpen`() [B.3.17] (see Section 12.4).
pKPOpenData	Kernel PlugIn driver-open data to be passed to `WD_KernelPlugInOpen`() (see the **WinDriver PCI Low-Level API Reference**). This parameter is applicable only when **`pcKPDriverName`** is not `NULL`; otherwise, set it to `NULL`.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

1. This function can be called from the **user mode only**.

2. If your card has a large memory range, which cannot be mapped entirely to the kernel virtual address space, you can modify the relevant item for this resource in the card resources information structure that you received from `WDC_PcmciaGetDeviceInfo`() [B.3.9], and set the `WD_ITEM_DO_NOT_MAP_KERNEL` flag in the item's `dwOptions` field (`pDeviceInfo->Card.Item[i].dwOptions`) before passing the information structure (`pDeviceInfo`) to `WDC_PcmciaDeviceOpen`(). This flag instructs the function to map the relevant memory range only to the user-mode virtual address space but not the kernel address space.

NOTE that if you select to set the `WD_ITEM_DO_NOT_MAP_KERNEL` flag, the device information structure that will be created by the function will not hold a kernel-mapped address for this resource (`pAddrDesc[i].kptAddr` in the `WDC_DEVICE` structure [B.4.3] for the relevant memory range will not be updated) and you will therefore not be able to rely on this mapping in calls to WinDriver's API or when accessing the memory from a Kernel PlugIn driver.

B.3.12. WDC_IsaDeviceOpen()

Purpose

Allocates and initializes a WDC ISA device structure, registers the device with WinDriver, and returns a handle to the device.

This function

- Verifies that none of the registered device resources (set in **`pDeviceInfo->Card.Item`**) are already locked for exclusive use.

  A resource can be locked for exclusive use by setting the `fNotSharable` field of its `WD_ITEMS` structure [B.5.10] to 1, before calling `WDC_IsaDeviceOpen`().

- Maps the device's physical memory ranges device both to kernel-mode and user-mode address space, and stores the mapped addresses in the allocated device structure for future use.

- Saves device resources information required for supporting the communication with the device. For example, the function saves the Interrupt Request (IRQ) number and the interrupt type, as well as retrieves and saves an interrupt handle, and this information is later used when the user calls functions to handle the device's interrupts.

- If the caller selects to use a Kernel PlugIn driver to communicate with the device, the function opens a handle to this driver and stores it for future use.

Prototype

```
DWORD DLLCALLCONV WDC_IsaDeviceOpen(
    WDC_DEVICE_HANDLE *phDev,
    const WD_CARD *pDeviceInfo,
    const PVOID pDevCtx,
    PVOID reserved,
    const CHAR *pcKPDriverName,
    PVOID pKPOpenData);
```

Parameters

Name	Type	Input/Output
phDev	WDC_DEVICE_HANDLE*	Output
pDeviceInfo	const WD_CARD*	Input
• dwItems	DWORD	Input
• Item	WD_ITEMS[WD_CARD_ITEMS]	Input
* item	DWORD	Input
* fNotSharable	DWORD	Input
• dwReserved	DWORD	N/A
• dwOptions	DWORD	Input
* I	union	Input
• Mem	struct	Input
* dwPhysicalAddr	DWORD	Input
* dwBytes	DWORD	Input
* dwTransAddr	DWORD	N/A
* dwUserDirectAddr	DWORD	N/A
* dwCpuPhysicalAddr	DWORD	N/A
* dwBar	DWORD	Input
• IO	struct	Input
* dwAddr	DWORD	Input
* dwBytes	DWORD	Input
* dwBar	DWORD	Input
• Int	struct	Input
* dwInterrupt	DWORD	Input
* dwOptions	DWORD	Input
* hInterrupt	DWORD	N/A
• Bus	struct	Input
* dwBusType	WD_BUS_TYPE	Input

Name	Type	Input/Output
* dwBusNum	DWORD	Input
* dwSlotFunc	DWORD	Input
• Val	struct	N/A
pDevCtx	const PVOID	Input
reserved	PVOID	N/A
pcKPDriverName	const CHAR*	Input
pKPOpenData	PVOID	Input

Description

Name	Description
phDev	Pointer to a handle to the WDC device allocated by the function
pDeviceInfo	Pointer to a card information structure [B.5.11], which contains information regarding the device to open
pDevCtx	Pointer to device context information, which will be stored in the device structure
reserved	Reserved for future use
pcKPDriverName	Kernel PlugIn driver name. Set to `NULL` when not required. This parameter is used to open a handle to a Kernel PlugIn driver together with opening a handle to the device. Note that this method cannot be used to acquire a handle to a 64-bit Kernel PlugIn driver from a 32-bit application. It is therefore recommended to open a Kernel PlugIn handle (when necessary) using `WDC_KernelPlugInOpen`() [B.3.17] (see Section 12.4).
pKPOpenData	Kernel PlugIn driver-open data to be passed to `WD_KernelPlugInOpen`() (see the **WinDriver PCI Low-Level API Reference**). This parameter is applicable only when **`pcKPDriverName`** is not `NULL`; otherwise, set it to `NULL`.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

1. This function can be called from the **user mode only**.

2. If your card has a large memory range, which cannot be mapped entirely to the kernel virtual address space, you can set the `WD_ITEM_DO_NOT_MAP_KERNEL` flag for the relevant memory `WD_ITEMS` structure [B.5.10] (`pDeviceInfo->Card.Item[i].dwOptions`) in order to instruct the function to map this memory range only to the user-mode virtual address space but not the kernel address space.

NOTE that if you select to set the `WD_ITEM_DO_NOT_MAP_KERNEL` flag, the device information structure that will be created by the function will not hold a kernel-mapped address for this resource (`pAddrDesc[i].kptAddr` in the `WDC_DEVICE` structure [B.4.3] for the relevant memory range will not be updated) and you will therefore not be able to rely on this mapping in calls to WinDriver's API or when accessing the memory from a Kernel PlugIn driver.

B.3.13. WDC_PciDeviceClose()

Purpose

Uninitializes a WDC PCI device structure and frees the memory allocated for it.

Prototype

```
DWORD DLLCALLCONV WDC_PciDeviceClose(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.10]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function can be called from the **user mode only**.

B.3.14. WDC_PcmciaDeviceClose()

Purpose

Uninitializes a WDC PCMCIA device structure and frees the memory allocated for it.

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaDeviceClose(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC PCMCIA device structure, returned by `WDC_PcmciaDeviceOpen()` [B.3.11]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function can be called from the **user mode only**.

B.3.15. WDC_IsaDeviceClose()

Purpose

Uninitializes a WDC ISA device structure and frees the memory allocated for it.

Prototype

```
DWORD DLLCALLCONV WDC_IsaDeviceClose(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC ISA device structure, returned by `WDC_IsaDeviceOpen`() [B.3.12]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function can be called from the **user mode only**.

B.3.16. WDC_CardCleanupSetup()

Purpose

Sets a list of transfer cleanup commands to be performed for the specified card on any of the following occasions:

- The application exits abnormally.
- The application exits normally but without closing the specified card.
- If the `bForceCleanup` parameter is set to `TRUE`, the cleanup commands will also be performed when the specified card is closed.

Prototype

```
DWORD WDC_CardCleanupSetup(
    WDC_DEVICE_HANDLE hDev,
    WD_TRANSFER *Cmd,
    DWORD dwCmds,
    BOOL bForceCleanup);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
Cmd	WD_TRANSFER*	Input
dwCmds	DWORD	Input
bForceCleanup	BOOL	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
Cmd	Pointer to an array of cleanup transfer commands to be performed [B.5.15]
dwCmds	Number of cleanup commands in the `Cmd` array
bForceCleanup	If **`FALSE`**: The cleanup transfer commands (`Cmd`) will be performed in either of the following cases: • When the application exist abnormally. • When the application exits normally without closing the card by calling one of the `WDC_xxxDeviceClose()` functions (PCI [B.3.13] / PCMCIA [B.3.14] / ISA [B.3.15]). If **`TRUE`**: The cleanup transfer commands will be performed both in the two cases described above, as well as in the following case: • When the relevant `WD_xxxDeviceClose()` function is called for the card.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.17. WDC_KernelPlugInOpen()

Purpose

Opens a handle to a Kernel PlugIn driver.

Prototype

```
DWORD DLLCALLCONV WDC_KernelPlugInOpen(
    WDC_DEVICE_HANDLE hDev,
    const CHAR *pcKPDriverName,
    PVOID pKPOpenData);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input/Output
pcKPDriverName	const CHAR*	Input
pKPOpenData	PVOID	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
pcKPDriverName	Kernel PlugIn driver name
pKPOpenData	Kernel PlugIn driver open data to be passed to `WD_KernelPlugInOpen()` (see the **WinDriver PCI Low-Level API Reference**)

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

It's also possible to use the `WDC_xxxDeviceOpen()` functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) to open a handle to a Kernel PlugIn driver, as part of the device-open operation. However, this method cannot be used to open a handle to a 64-bit Kernel PlugIn driver from a 32-bit user-mode application. Therefore, to ensure that your code works in all the supported configurations, it is recommended that you use `WDC_KernelPlugInOpen()` to open the Kernel PlugIn driver handle. This is also the only supported method for opening a Kernel PlugIn handle from a .NET application. (See detailed information in Section 12.4.)

B.3.18. WDC_CallKerPlug()

Purpose

Sends a message from a user-mode application to a Kernel PlugIn driver. The function passes a message ID from the application to the Kernel PlugIn's `KP_Call` [B.6.4] function, which should be implemented to handle the specified message ID, and returns the result from the Kernel PlugIn to the user-mode application.

Prototype

```
DWORD DLLCALLCONV WDC_CallKerPlug(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwMsg,
    PVOID pData,
    PDWORD pdwResult);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwMsg	DWORD	Input
pData	PVOID	Input/Output
pdwResult	pdwResult	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
dwMsg	A message ID to pass to the Kernel PlugIn driver (specifically to `KP_Call` [B.6.4])
pData	Pointer to data to pass between the Kernel PlugIn driver and the user-mode application
pdwResult	Result returned by the Kernel PlugIn driver (`KP_Call`) for the operation performed in the kernel as a result of the message that was sent

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.19. WDC_ReadMemXXX()

Purpose

`WDC_ReadMem8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified memory address. The address is read directly in the calling context (user mode / kernel mode).

Prototype

```
BYTE WDC_ReadMem8(addr, off);
WORD WDC_ReadMem16(addr, off);
UINT32 WDC_ReadMem32(addr, off);
UINT64 WDC_ReadMem64(addr, off);
```

Note: The `WDC_ReadMemXXX` APIs are implemented as macros. The prototypes above use functions declaration syntax to emphasize the expected return values.

Parameters

Name	Type	Input/Output
addr	DWORD	Input
off	DWORD	Input

Description

Name	Description
addr	The memory address space to read from
off	The offset from the beginning of the specified address space (`addr`) to read from

Return Value

Returns the data that was read from the specified address.

B.3.20. WDC_WriteMemXXX()

Purpose

`WDC_WriteMem8/16/32/64`() writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified memory address. The address is written to directly in the calling context (user mode / kernel mode).

Prototype

```
void WDC_WriteMem8(addr, off, val);
void WDC_WriteMem16(addr, off, val);
void WDC_WriteMem32(addr, off, val);
void WDC_WriteMem64(addr, off, val);
```

Note: The `WDC_WriteMemXXX` APIs are implemented as macros. The prototypes above use functions declaration syntax to emphasize the expected return values.

Parameters

Name	Type	Input/Output
addr	DWORD	Input
off	DWORD	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
addr	The memory address space to read from
off	The offset from the beginning of the specified address space (`addr`) to read from
val	The data to write to the specified address

Return Value

None

B.3.21. WDC_ReadAddrXXX()

Purpose

`WDC_ReadAddr8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified memory or I/O address.

Prototype

```
DWORD DLLCALLCONV WDC_ReadAddr8(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, BYTE *val);

DWORD DLLCALLCONV WDC_ReadAddr16(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, WORD *val);

DWORD DLLCALLCONV WDC_ReadAddr32(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT32 *val);

DWORD DLLCALLCONV WDC_ReadAddr64(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT64 *val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
val	BYTE* / WORD* / UINT32* / UINT64*	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
dwAddrSpace	The memory or I/O address space to read from
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to read from
val	Pointer to a buffer to be filled with the data that is read from the specified address

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.22. WDC_WriteAddrXXX()

Purpose

`WDC_WriteAddr8/16/32/64()` writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified memory or I/O address.

Prototype

```
DWORD DLLCALLCONV WDC_WriteAddr8(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, BYTE val)

DWORD DLLCALLCONV WDC_WriteAddr16(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, WORD val);

DWORD DLLCALLCONV WDC_WriteAddr32(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT32 val);

DWORD DLLCALLCONV WDC_WriteAddr64(WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace, KPTR dwOffset, UINT64 val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
dwAddrSpace	The memory or I/O address space to write to
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to write to
val	The data to write to the specified address

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.23. WDC_ReadAddrBlock()

Purpose

Reads a block of data from the device.

Prototype

```
DWORD DLLCALLCONV WDC_ReadAddrBlock(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace,
    KPTR dwOffset,
    DWORD dwBytes,
    PVOID pData,
    WDC_ADDR_MODE mode,
    WDC_ADDR_RW_OPTIONS options);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
dwBytes	DWORD	Input
pData	PVOID	Output
mode	WDC_ADDR_MODE	Input
options	WDC_ADDR_RW_OPTIONS	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
dwAddrSpace	The memory or I/O address space to read from
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to read from
dwBytes	The number of bytes to read
pData	Pointer to a buffer to be filled with the data that is read from the device
mode	The read access mode – see `WDC_ADDR_MODE` [B.3.1.4]
options	A bit mask that determines how the data will be read – see `WDC_ADDR_RW_OPTIONS` [B.3.1.5]. The function automatically sets the `WDC_RW_BLOCK` flag.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.24. WDC_WriteAddrBlock()

Purpose

Writes a block of data to the device.

Prototype

```
DWORD DLLCALLCONV WDC_WriteAddrBlock(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace,
    KPTR dwOffset,
    DWORD dwBytes,
    PVOID pData,
    WDC_ADDR_MODE mode,
    WDC_ADDR_RW_OPTIONS options);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input
dwOffset	KPTR	Input
dwBytes	DWORD	Input
pData	PVOID	Input
mode	WDC_ADDR_MODE	Input
options	WDC_ADDR_RW_OPTIONS	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
dwAddrSpace	The memory or I/O address space to write to
dwOffset	The offset from the beginning of the specified address space (`dwAddrSpace`) to write to
dwBytes	The number of bytes to write
pData	Pointer to a buffer that holds the data to write to the device
mode	The write access mode – see `WDC_ADDR_MODE` [B.3.1.4]
options	A bit mask that determines how the data will be written – see `WDC_ADDR_RW_OPTIONS` [B.3.1.5]. The function automatically sets the `WDC_RW_BLOCK` flag.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.25. WDC_MultiTransfer()

Purpose

Performs a group of memory and/or I/O read/write transfers.

Prototype

```
DWORD DLLCALLCONV WDC_MultiTransfer(
    WD_TRANSFER *pTrans,
    DWORD dwNumTrans);
```

Parameters

Name	Type	Input/Output
pTrans	WD_TRANSFER*	
dwNumTrans	DWORD	Input

Description

Name	Description
pTrans	Pointer to an array of transfer commands information structures [B.5.15]
dwNumTrans	Number of transfer commands in the `pTrans` array

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- The transfers are performed using the low-level `WD_MultiTransfer`() WinDriver function, which reads/writes the specified addresses in the kernel (see the **WinDriver PCI Low-Level API Reference** for details).
- Memory addresses are read/written in the kernel (like I/O addresses) and NOT directly in the user mode, therefore the port addresses passed to this function, for both memory and I/O addresses, must be the kernel-mode mappings of the physical addresses, which are stored in the device structure [B.4.3].

B.3.26. WDC_AddrSpaceIsActive()

Purpose

Checks if the specified memory or I/O address space is active – i.e., if its size is not zero.

Prototype

```
BOOL DLLCALLCONV WDC_AddrSpaceIsActive(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwAddrSpace);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwAddrSpace	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
dwAddrSpace	The memory or I/O address space to look for

Return Value

Returns `TRUE` if the specified address space is active; otherwise returns `FALSE`.

B.3.27. WDC_PciReadCfgBySlot()

Purpose

Reads data from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfgBySlot(
    WD_PCI_SLOT *pPciSlot,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
pData	PVOID	Output
dwBytes	DWORD	Input

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.5.8], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to read from
pData	Pointer to a buffer to be filled with the data that is read from the PCI configuration space
dwBytes	The number of bytes to read

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.28. WDC_PciWriteCfgBySlot()

Purpose

Write data to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfgBySlot(
    WD_PCI_SLOT *pPciSlot,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
pData	PVOID	Input
dwBytes	DWORD	Input

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.5.8], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to write to
pData	Pointer to a data buffer that holds the data to write
dwBytes	The number of bytes to write

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.29. WDC_PciReadCfg()

Purpose

Reads data from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfg(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pData	PVOID	Output
dwBytes	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen()` [B.3.10]
dwOffset	The offset from the beginning of the PCI configuration space to read from
pData	Pointer to a buffer to be filled with the data that is read from the PCI configuration space
dwBytes	The number of bytes to read

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.30. WDC_PciWriteCfg()

Purpose

Writes data to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfg(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pData	PVOID	Input
dwBytes	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.10]
dwOffset	The offset from the beginning of the PCI configuration space to write to
pData	Pointer to a data buffer that holds the data to write
dwBytes	The number of bytes to write

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.31. WDC_PciReadCfgBySlotXXX()

Purpose

`WDC_PciReadCfgBySlot8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfgRegBySlot8(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, BYTE *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg1BySlot6(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, WORD *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg32BySlot(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT32 *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg64BySlot(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT64 *val);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
val	BYTE* / WORD* / UINT32* / UINT64*	Output

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.5.8], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	Pointer to a buffer to be filled with the data that is read from the PCI configuration space

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.32. WDC_PciWriteCfgBySlotXXX()

Purpose

`WDC_PciWriteCfgBySlot8/16/32/64`() writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.
The device is identified by its location on the PCI bus.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot8(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, BYTE val);

DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot16(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, WORD val);

DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot32(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT32 val);

DWORD DLLCALLCONV WDC_PciWriteCfgRegBySlot64(
    WD_PCI_SLOT *pPciSlot, DWORD dwOffset, UINT64 val);
```

Parameters

Name	Type	Input/Output
pPciSlot	WD_PCI_SLOT*	Input
dwOffset	DWORD	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
pPciSlot	Pointer to a PCI device location information structure [B.5.8], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	The data to write to the PCI configuration space

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.33. WDC_PciReadCfgXXX()

Purpose

`WDC_PciReadCfg8/16/32/64`() reads 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, from a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciReadCfgReg8(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, BYTE *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg16(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, WORD *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg32(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT32 *val);

DWORD DLLCALLCONV WDC_PciReadCfgReg64(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT64 *val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
val	BYTE* / WORD* / UINT32* / UINT64*	Output

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.10]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	Pointer to a buffer to be filled with the data that is read from the PCI configuration space

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.34. WDC_PciWriteCfgXXX()

Purpose

`WDC_PciWriteCfg8/16/32/64`() writes 1 byte (8 bits) / 2 bytes (16 bits) / 4 bytes (32 bits) / 8 bytes (64 bits), respectively, to a specified offset in a PCI device's configuration space or a PCI Express device's extended configuration space.

Access to the PCI Express extended configuration space is supported on target platforms that support such access (e.g., Windows, Mac OS X, and Linux). For such platforms, all *PCI* references in the following documentation include PCI Express as well.

Prototype

```
DWORD DLLCALLCONV WDC_PciWriteCfgReg8(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, BYTE val);

DWORD DLLCALLCONV WDC_PciWriteCfgReg16(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, WORD val);

DWORD DLLCALLCONV WDC_PciWriteCfgReg32(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT32 val);

DWORD DLLCALLCONV WDC_PciWriteCfgReg64(WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset, UINT64 val);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
val	BYTE / WORD / UINT32 / UINT64	Input

Description

Name	Description
hDev	Handle to a WDC PCI device structure, returned by `WDC_PciDeviceOpen`() [B.3.10]
dwOffset	The offset from the beginning of the PCI configuration space to read from
val	The data to write to the PCI configuration space

Return Value

Returns WD_STATUS_SUCCESS (0) on success, or an appropriate error code otherwise [B.9].

B.3.35. WDC_PcmciaReadAttribSpace()

Purpose

Reads data from a specified offset in a PCMCIA device's attribute space.

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaReadAttribSpace(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pData	PVOID	Output
dwBytes	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC PCMCIA device structure, returned by WDC_PcmciaDeviceOpen() [B.3.11]
dwOffset	The offset from the beginning of the PCMCIA attribute space to read from
pData	Pointer to a buffer to be filled with the data that is read from the PCMCIA attribute space
dwBytes	The number of bytes to read

Return Value

Returns WD_STATUS_SUCCESS (0) on success, or an appropriate error code otherwise [B.9].

B.3.36. WDC_PcmciaWriteAttribSpace()

Purpose

Writes data to a specified offset in a PCMCIA device's attribute space.

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaWriteAttribSpace(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwOffset,
    PVOID pData,
    DWORD dwBytes);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwOffset	DWORD	Input
pData	PVOID	Input
dwBytes	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC PCMCIA device structure, returned by `WDC_PcmciaDeviceOpen()` [B.3.11]
dwOffset	The offset from the beginning of the PCMCIA attribute space to write to
pData	Pointer to a data buffer that holds the data to write
dwBytes	The number of bytes to write

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.37. WDC_PcmciaSetWindow()

Purpose

Modifies the settings of the PCMCIA bus controller's memory window.

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaSetWindow(
    WDC_DEVICE_HANDLE hDev,
    WD_PCMCIA_ACC_SPEED speed,
    WD_PCMCIA_ACC_WIDTH width,
    DWORD dwCardBase);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
speed	WD_PCMCIA_ACC_SPEED	Input
width	WD_PCMCIA_ACC_WIDTH	Input
dwCardBase	DWORD	Input

Description

Name	Description
hDev	Handle to a WDC PCMCIA device structure, returned by `WDC_PcmciaDeviceOpen()` [B.3.11]
speed	The access speed to the PCMCIA bus – see the `WD_PCMCIA_ACC_SPEED` enumeration [B.5.3]
width	The PCMCIA bus width – see the `WD_PCMCIA_ACC_WIDTH` enumeration [B.5.4]
dwCardBase	The offset in the PCMCIA device's memory from which the memory mapping begins

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.38. WDC_PcmciaSetVpp()

Purpose

Modifies the power level of the PCMCIA bus controller's Voltage Power Pin (Vpp).

Prototype

```
DWORD DLLCALLCONV WDC_PcmciaSetVpp(
    WDC_DEVICE_HANDLE hDev,
    WD_PCMCIA_VPP vpp);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
vpp	WD_PCMCIA_VPP	Input

Description

Name	Description
hDev	Handle to a WDC PCMCIA device structure, returned by `WDC_PcmciaDeviceOpen()` [B.3.11]
vpp	The power level of the PCMCIA controller's Voltage Power Pin (Vpp) – see the `WD_PCMCIA_VPP` enumeration [B.5.5]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.39. WDC_DMAContigBufLock()

Purpose

Allocates a contiguous DMA buffer, locks it in physical memory, and returns mappings of the allocated buffer to physical address space and to user-mode and kernel virtual address spaces.

Prototype

```
DWORD DLLCALLCONV WDC_DMAContigBufLock(
    WDC_DEVICE_HANDLE hDev,
    PVOID *ppBuf,
    DWORD dwOptions,
    DWORD dwDMABufSize,
    WD_DMA **ppDma);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
ppBuf	PVOID*	Output
dwOptions	DWORD	Input
dwDMABufSize	DWORD	Input
ppDma	WD_DMA**	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]).
ppBuf	Pointer to a pointer to be filled by the function with the user-mode mapped address of the allocated DMA buffer
dwOptions	A bit mask of any of the following flags (defined in an enumeration in **windrvr.h**): • **`DMA_FROM_DEVICE`**: Synchronize the DMA buffer for transfers from the device to memory. • **`DMA_TO_DEVICE`**: Synchronize the DMA buffer for transfers from memory to the device. • **`DMA_TO_FROM_DEVICE`**: Synchronize the DMA buffer for transfers in both directions – i.e., from the device to memory and from memory to the device (<=> `DMA_FROM_DEVICE | DMA_TO_DEVICE`). • **`DMA_ALLOW_CACHE`**: Allow caching of the memory. • **`DMA_KBUF_BELOW_16M`**: Allocate the physical DMA buffer within the lower 16MB of the main memory. • **`DMA_ALLOW_64BIT_ADDRESS`**: Allow allocation of 64-bit DMA addresses. This flag is supported on Windows, Mac OS X, and Linux.
dwDMABufSize	The size (in bytes) of the DMA buffer
ppDma	Pointer to a pointer to a DMA buffer information structure [B.5.14], which is allocated by the function. The pointer to this structure (`*ppDma`) should be passed to `WDC_DMABufUnlock()` [B.3.41] when the DMA buffer is no longer needed.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- When calling this function you do **not** need to set the `DMA_KERNEL_BUFFER_ALLOC` flag, since the function sets this flag automatically.
- This function is currently only supported from the user mode.
- On Windows x86 and x86_64 platforms, you should normally set the `DMA_ALLOW_CACHE` flag in the DMA options bitmask parameter (`dwOptions`).

- If the device supports 64-bit DMA addresses, it is recommended to set the `DMA_ALLOW_64BIT_ADDRESS` flag in `dwOptions`. Otherwise, when the physical memory on the target platform is larger than 4GB, the operating system may only allow allocation of relatively small 32-bit DMA buffers (such as 1MB buffers, or even smaller).

- On Mac OS X, if there aren't enough resources to accommodate the DMA buffer allocation request, the process will hang (refer to the Mac OS X note in Section 9.1).

B.3.40. WDC_DMASGBufLock()

Purpose

Locks a pre-allocated user-mode memory buffer for DMA and returns the corresponding physical mappings of the locked DMA pages. On Windows 7/Vista/Server 2008/Server 2003/XP the function also returns a kernel-mode mapping of the buffer.

Prototype

```
DWORD DLLCALLCONV WDC_DMASGBufLock(
    WDC_DEVICE_HANDLE hDev,
    PVOID pBuf,
    DWORD dwOptions,
    DWORD dwDMABufSize,
    WD_DMA **ppDma);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
pBuf	PVOID	Input
dwOptions	DWORD	Input
dwDMABufSize	DWORD	Input
ppDma	WD_DMA**	Output

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
pBuf	Pointer to a user-mode buffer to be mapped to the allocated physical DMA buffer(s)
dwOptions	A bit mask of any of the following flags (defined in an enumeration in **windrvr.h**): • **`DMA_FROM_DEVICE`**: Synchronize the DMA buffer for transfers from the device to memory. • **`DMA_TO_DEVICE`**: Synchronize the DMA buffer for transfers from memory to the device. • **`DMA_TO_FROM_DEVICE`**: Synchronize the DMA buffer for transfers in both directions – i.e., from the device to memory and from memory to the device (<=> `DMA_FROM_DEVICE | DMA_TO_DEVICE`). • **`DMA_ALLOW_CACHE`**: Allow caching of the memory. • **`DMA_ALLOW_64BIT_ADDRESS`**: Allow allocation of 64-bit DMA addresses. This flag is supported on Windows, Mac OS X, and Linux.
dwDMABufSize	The size (in bytes) of the DMA buffer
ppDma	Pointer to a pointer to a DMA buffer information structure [B.5.14], which is allocated by the function. The pointer to this structure (`*ppDma`) should be passed to `WDC_DMABufUnlock()` [B.3.41] when the DMA buffer is no longer needed.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- When calling the function to allocate large buffers (> 1MB) you do **not** need to set the `DMA_LARGE_BUFFER` flag, which is used for allocation of large Scatter/Gather DMA buffers using the low-level WinDriver `WD_DMALock()` function (see the **WinDriver PCI Low-Level API Reference**), since `WDC_DMASGBufLock()` handles this for you.

- This function is currently only supported from the user mode.

- On Windows x86 and x86_64 platforms, you should normally set the `DMA_ALLOW_CACHE` flag in the DMA options bitmask parameter (`dwOptions`).

- If the device supports 64-bit DMA addresses, it is recommended to set the `DMA_ALLOW_64BIT_ADDRESS` flag in `dwOptions`. Otherwise, when the physical memory on the target platform is larger than 4GB, the operating system may only allow allocation of relatively small 32-bit DMA buffers (such as 1MB buffers, or even smaller).

- On Mac OS X, if there aren't enough resources to accommodate the DMA buffer allocation request, the process will hang (refer to the Mac OS X note in Section 9.1).

B.3.41. WDC_DMABufUnlock()

Purpose

Unlocks and frees the memory allocated for a DMA buffer by a previous call to `WDC_DMAContigBufLock`() [B.3.39] or `WDC_DMASGBufLock`() [B.3.40].

Prototype

```
DWORD DLLCALLCONV WDC_DMABufUnlock(WD_DMA *pDma);
```

Parameters

Name	Type	Input/Output
pDma	WD_DMA*	Input

Description

Name	Description
pDma	Pointer to a DMA information structure [B.5.14], received from a previous call to `WDC_DMAContigBufLock`() [B.3.39] (for a Contiguous DMA buffer) or `WDC_DMASGBufLock`() [B.3.40] (for a Scatter/Gather DMA buffer) – `*ppDma` returned by these functions

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function is currently only supported from the user mode.

B.3.42. WDC_DMASyncCpu()

Purpose

Synchronizes the cache of all CPUs with the DMA buffer, by flushing the data from the CPU caches.

This function should be called before performing a DMA transfer (see Remarks below).

Prototype

```
DWORD DLLCALLCONV WDC_DMASyncCpu(WD_DMA *pDma);
```

Parameters

Name	Type	Input/Output
pDma	WD_DMA*	Input

Description

Name	Description
pDma	Pointer to a DMA information structure [B.5.14], received from a previous call to `WDC_DMAContigBufLock`() [B.3.39] (for a Contiguous DMA buffer) or `WDC_DMASGBufLock`() [B.3.40] (for a Scatter/Gather DMA buffer) – `*ppDma` returned by these functions

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- An asynchronous DMA read or write operation accesses data in memory, not in the processor (CPU) cache, which resides between the CPU and the host's physical memory. Unless the CPU cache has been flushed, by calling `WDC_DMASyncCpu`(), just before a read transfer, the data transferred into system memory by the DMA operation could be overwritten with stale data if the CPU cache is flushed later. Unless the CPU cache has been flushed by calling `WDC_DMASyncCpu`() just before a write transfer, the data in the CPU cache might be more up-to-date than the copy in memory.

- This function is currently only supported from the user mode.

B.3.43. WDC_DMASyncIo()

Purpose

Synchronizes the I/O caches with the DMA buffer, by flushing the data from the I/O caches and updating the CPU caches.

This function should be called after performing a DMA transfer (see Remarks below).

Prototype

```
DWORD DLLCALLCONV WDC_DMASyncIo(WD_DMA *pDma);
```

Parameters

Name	Type	Input/Output
pDma	WD_DMA*	Input

Description

Name	Description
pDma	Pointer to a DMA information structure, received from a previous call to `WDC_DMAContigBufLock()` [B.3.39] (for a Contiguous DMA buffer) or `WDC_DMASGBufLock()` [B.3.40] (for a Scatter/Gather DMA buffer) – `*ppDma` returned by these functions

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- After a DMA transfer has been completed, the data can still be in the I/O cache, which resides between the host's physical memory and the bus-master DMA device, but not yet in the host's main memory. If the CPU accesses the memory, it might read the wrong data from the CPU cache. To ensure a consistent view of the memory for the CPU, you should call `WDC_DMASyncIo()` after a DMA transfer in order to flush the data from the I/O cache and update the CPU cache with the new data. The function also flushes additional caches and buffers between the device and memory, such as caches associated with bus extenders or bridges.

- This function is currently only supported from the user mode.

B.3.44. WDC_SharedBufferAlloc()

Purpose

Allocates a memory buffer that can be shared between the user mode and the kernel mode (**"shared buffer"**), and returns user-mode and kernel-mode virtual address space mappings of the allocated buffer.

This function provides a useful method for sharing data between a user-mode application and a Kernel PlugIn driver.

Prototype

```
DWORD DLLCALLCONV WDC_SharedBufferAlloc(
    PVOID *ppUserAddr,
    KPTR *ppKernelAddr,
    DWORD dwBufSize,
    DWORD dwOptions,
    HANDLE *phBuf);
```

Parameters

Name	Type	Input/Output
*ppUserAddr	PVOID*	Output
*ppKernelAddr	KPTR*	Output
dwBufSize	DWORD	Input
dwOptions	DWORD	Input
phBuf	HANDLE*	Output

Description

Name	Description
ppUserAddr	Pointer to a pointer to be filled by the function with the user-mode mapped address of the allocated buffer
ppKernelAddr	Pointer to a pointer to be filled by the function with the kernel-mode mapped address of the allocated buffer
dwBufSize	The size of the buffer to allocate, in bytes
dwOptions	Reserved for future use. Initialize this field to 0.
phBuf	Pointer to a handle to the allocated buffer, to be filled by the function. When the buffer is no longer needed, the handle to the buffer (`*phBuf`) should be passed to `WDC_SharedBufferFree`() [B.3.45].

Return Value

Returns WD_STATUS_SUCCESS (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function is currently only supported from the user mode.

B.3.45. WDC_SharedBufferFree()

Purpose

Frees a shared buffer that was allocated by a previous call to WDC_SharedBufferAlloc() [B.3.44].

Prototype

```
#define WDC_SharedBufferFree(hBuf)
```

Parameters

Name	Type	Input/Output
hBuf	HANDLE	Input

Description

Name	Description
hBuf	Handle to a shared buffer, received within the *phBuf parameter of a previous call to WDC_SharedBufferAlloc() [B.3.44]

Return Value

Returns WD_STATUS_SUCCESS (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function is currently only supported from the user mode.

B.3.46. WDC_IntEnable()

Purpose

Enables interrupt handling for the device.
On Linux, Mac OS X, and Windows Vista and higher, when attempting to enable interrupts for a PCI device that supports Extended Message-Signaled Interrupts (MSI-X) or Message-Signaled Interrupts (MSI) (and was installed with a relevant INF file – on Windows Vista and higher [9.2.6.1]), the function first tries to enable MSI-X or MSI; if this fails, or if the target OS does not support MSI/MSI-X, the function attempts to enable legacy level-sensitive interrupts (if supported by the device). For other types of hardware (PCI with no MSI/MSI-X support / PCMCIA / ISA), the function attempts to enable the legacy interrupt type supported by the device (Level Sensitive / Edge Triggered) – see further information in Section 9.2.

When enabling interrupts using a **Kernel PlugIn** driver (`fUseKP=TRUE`), the Kernel PlugIn functions used to handle the interrupts are derived from the type of interrupts enabled for the device: for MSI/MSI-X, the `KP_IntAtIrqlMSI` and `KP_IntAtDpcMSI` functions are used; otherwise, the `KP_IntAtIrql` and `KP_IntAtDpc` functions are used.

If the caller selects to handle the interrupts in the kernel, using a **Kernel PlugIn** driver, the Kernel PlugIn `KP_IntAtIrql` [B.6.8] (legacy interrupts) or `KP_IntAtIrqlMSI` [B.6.10] (MSI/MSI-X) function, which runs at high Interrupt Request (IRQ) level, will be invoked immediately when an interrupt is received.

The function can receive transfer commands information, which will be performed by WinDriver at the kernel, at high IRQ level, when an interrupt is received (see further information in Section 9.2.5). If a **Kernel PlugIn** driver is used to handle the interrupts, any transfer commands set by the caller will be executed by WinDriver after the Kernel PlugIn `KP_IntAtDpc` or `KP_IntAtDpcMSI` function completes its execution.
When handling level-sensitive interrupts (such as legacy PCI interrupts) from the **user mode**, without a Kernel PlugIn driver, you must prepare and pass to the function transfer commands for acknowledging the interrupt. When using a **Kernel PlugIn** driver, the information for acknowledging the interrupts should be implemented in the Kernel PlugIn `KP_IntAtIrql` function [B.6.8], so the transfer commands in the call to `WDC_IntEnable`() are not required (although they can still be used).

The function receives a user-mode interrupt handler routine, which will be called by WinDriver after the kernel-mode interrupt processing is completed.
If the interrupts are handled using a **Kernel PlugIn** driver, the return value of the Kernel PlugIn deferred interrupt handler function – `KP_IntAtDpc` [B.6.9] (legacy interrupts) or `KP_IntAtDpcMSI` [B.6.11] (MSI/MSI-X) – will determine how many times (if at all) the user-mode interrupt handler will be called (provided `KP_IntAtDpc` or `KP_IntAtDpcMSI` itself is executed – which is determined by the return value of the Kernel PlugIn `KP_IntAtIrql` [B.6.8] or `KP_IntAtIrqlMSI` [B.6.10] function).

Prototype

```
DWORD DLLCALLCONV WDC_IntEnable(
    WDC_DEVICE_HANDLE hDev,
    WD_TRANSFER *pTransCmds,
    DWORD dwNumCmds,
    DWORD dwOptions,
    INT_HANDLER funcIntHandler,
    PVOID pData,
    BOOL fUseKP);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
pTransCmds	WD_TRANSFER*	Input
dwNumCmds	DWORD	Input
dwOptions	DWORD	Input
funcIntHandler	typedef void (*INT_HANDLER)(PVOID pData);	Input
pData	PVOID	Input
fUseKP	BOOL	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])
pTransCmds	An array of transfer commands information structures that define the operations to be performed at the kernel level upon the detection of an interrupt, or `NULL` if no transfer commands are required. NOTE: • Memory allocated for the transfer commands must remain available until the interrupts are disabled . • When handling level-sensitive interrupts (such as legacy PCI interrupts) without a Kernel PlugIn [11], you must use this array to define the hardware-specific commands for acknowledging the interrupts in the kernel, immediately when they are received – see further information in Section 9.2. For an explanation on how to set the transfer commands, refer to the description of `WD_TRANSFER` in Section B.5.15, and to the explanation in Section 9.2.5.
dwNumCmds	Number of transfer commands in the `pTransCmds` array

Name	Description
dwOptions	A bit mask of interrupt handling flags. Can be zero for no option, or: • **INTERRUPT_CMD_COPY**: If set, WinDriver will copy any data read in the kernel as a result of a read transfer command, and return it to the user within the relevant transfer command structure. The user will be able to access the data from his user-mode interrupt handler routine (**funcIntHandler**).
funcIntHandler	A user-mode interrupt handler callback function, which will be executed after an interrupt is received and processed in the kernel. (The prototype of the interrupt handler – INT_HANDLER – is defined in **windrvr_int_thread.h**).
pData	Data for the user-mode interrupt handler callback routine (**funcIntHandler**)
fUseKP	If **TRUE** – The device's Kernel PlugIn driver's KP_IntAtIrql [B.6.8] or KP_IntAtIrqlMSI [B.6.10] function, which runs at high Interrupt Request (IRQ) level, will be executed immediately when an interrupt is received. The Kernel PlugIn driver to be used for the device is passed to WDC_xxxDeviceOpen() and stored in the WDC device structure. If the caller also passes transfer commands to the function (**pTransCmds**), these commands will be executed by WinDriver at the kernel, at high IRQ level, after KP_IntAtIrql or KP_IntAtIrqlMSI completes its execution. If the high-IRQL handler returns TRUE, the Kernel PlugIn deferred interrupt processing routine – KP_IntAtDpc [B.6.9] or KP_IntAtDpcMSI [B.6.11] – will be invoked. The return value of this function determines how many times (if at all) the user-mode interrupt handler (**funcIntHandler**) will be executed once the control returns to the user mode. If **FALSE** – When an interrupt is received, any transfer commands set by the user in **pTransCmds** will be executed by WinDriver at the kernel, at high IRQ level, and the user-mode interrupt handler routine (**funcIntHandler**) will be executed when the control returns to the user mode.

Return Value

Returns WD_STATUS_SUCCESS (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function can be called from the **user mode only**.
- The function enables interrupt handling in the software. After it returns successfully you must physically enable generation of interrupts in the hardware (you should be able to do so by writing to the device from the code).
- A successful call to this function must be followed with a call to `WDC_IntDisable`() later on in the code, in order to disable the interrupts.
  The `WDC_xxxDriverClose`() functions (PCI: [B.3.13], PCMCIA: [B.3.14], ISA: [B.3.15]) call `WDC_IntDisable`() if the device's interrupts are enabled.
- WinDriver must be registered with the OS as the driver of the device before enabling interrupts. For Plug-and-Play hardware (PCI/PCI Express/PCMCIA) on Windows platforms, this association is made by installing an INF file for the device [15.1]. If the INF file is not installed, `WDC_IntEnable`() will fail with a `WD_NO_DEVICE_OBJECT` error [B.9].

B.3.47. WDC_IntDisable()

Purpose

Disables interrupt interrupt handling for the device, pursuant to a previous call to `WDC_IntEnable`() [B.3.46].

Prototype

```
DWORD DLLCALLCONV WDC_IntDisable(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen`() (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function can be called from the **user mode only**.

B.3.48. WDC_IntIsEnabled()

Purpose

Checks if a device's interrupts are currently enabled.

Prototype

```
BOOL DLLCALLCONV WDC_IntIsEnabled(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])

Return Value

Returns `TRUE` if the device's interrupts are enabled; otherwise returns `FALSE`.

B.3.49. WDC_EventRegister()

Purpose

Registers the application to receive Plug-and-Play and power management events notifications for the device.

Prototype

```
DWORD DLLCALLCONV WDC_EventRegister(
    WDC_DEVICE_HANDLE hDev,
    DWORD dwActions,
    EVENT_HANDLER funcEventHandler,
    PVOID pData,
    BOOL fUseKP);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input
dwActions	DWORD	Input
funcEventHandler	typedef void (*EVENT_HANDLER)(WD_EVENT *pEvent, void *pData);	Input
pData	PVOID	Input
fUseKP	BOOL	Input

Description

Name	Description
hDev	Handle to a Plug-and-Play WDC device, returned by `WDC_PciDeviceOpen()` [B.3.10] or `WDC_PcmciaDeviceOpen()` [B.3.11]
dwActions	A bit mask of flags indicating which events to register to: **Plug-and-Play events:** • **`WD_INSERT`** – Device inserted • **`WD_REMOVE`** – Device removed **Device power state change events:** • **`WD_POWER_CHANGED_D0`** – Full power • **`WD_POWER_CHANGED_D1`** – Low sleep • **`WD_POWER_CHANGED_D2`** – Medium sleep • **`WD_POWER_CHANGED_D3`** – Full sleep • **`WD_POWER_SYSTEM_WORKING`** – Fully on **Systems power state:** • **`WD_POWER_SYSTEM_SLEEPING1`** – Fully on but sleeping • **`WD_POWER_SYSTEM_SLEEPING2`** – CPU off, memory on, PCI/PCMCIA on • **`WD_POWER_SYSTEM_SLEEPING3`** – CPU off, Memory is in refresh, PCI/PCMCIA on aux power • **`WD_POWER_SYSTEM_HIBERNATE`** – OS saves context before shutdown • **`WD_POWER_SYSTEM_SHUTDOWN`** – No context saved
funcEventHandler	A user-mode event handler callback function, which will be called when an event for which the caller registered to receive notifications (see **`dwActions`**) occurs. (The prototype of the event handler – `EVENT_HANDLER` – is defined in **windrvr_events.h**).
pData	Data for the user-mode event handler callback routine (**`funcEventHandler`**)
fUseKP	If **`TRUE`** – When an event for which the caller registered to receive notifications (**`dwActions`**) occurs, the device's Kernel PlugIn driver's `KP_Event` function [B.6.5] will be called. (The Kernel PlugIn driver to be used for the device is passed to `WDC_xxxDeviceOpen()` and stored in the WDC device structure). If this function returns `TRUE`, the user-mode events handler callback function (**`funcEventHandler`**) will be called when the kernel-mode event processing is completed. If **`FALSE`** – When an event for which the caller registered to receive notifications (**`dwActions`**) occurs, the user-mode events handler callback function will be called.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function can be called from the **user mode only**.
- A successful call to this function must be followed with a call to `WDC_EventUnregister`() [B.3.50] later on in the code, in order to unregister from receiving Plug-and-play and power management notifications from the device.

B.3.50. WDC_EventUnregister()

Purpose

Unregisters an application from a receiving Plug-and-Play and power management notifications for a device, pursuant to a previous call to `WDC_EventRegister`() [B.3.49].

Prototype

```
DWORD DLLCALLCONV WDC_EventUnregister(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a Plug-and-Play WDC device, returned by `WDC_PciDeviceOpen`() [B.3.10] or `WDC_PcmciaDeviceOpen`() [B.3.11]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

- This function can be called from the **user mode only**.

B.3.51. WDC_EventIsRegistered()

Purpose

Checks if the application is currently registered to receive Plug-and-Play and power management notifications for the device.

Prototype

```
BOOL DLLCALLCONV WDC_EventIsRegistered(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a Plug-and-Play WDC device, returned by `WDC_PciDeviceOpen`() [B.3.10] or `WDC_PcmciaDeviceOpen`() [B.3.11]

Return Value

Returns `TRUE` if the application is currently registered to receive Plug-and-Play and power management notifications for the device; otherwise returns `FALSE`.

B.3.52. WDC_SetDebugOptions()

Purpose

Sets debug options for the WDC library – see the description of `WDC_DBG_OPTIONS` [B.3.1.8] for details regarding the possible debug options to set.

This function is typically called at the beginning of the application, after the call to `WDC_DriverOpen`() [B.3.2], and can be re-called at any time while the WDC library is in use (i.e., `WDC_DriverClose`() [B.3.3] has not been called) in order to change the debug settings.

Until the function is called, the WDC library uses the default debug options – see `WDC_DBG_DEFAULT` [B.3.1.8].

When the function is recalled, it performs any required cleanup for the previous debug settings and sets the default debug options before attempting to set the new options specified by the caller.

Prototype

```
DWORD DLLCALLCONV WDC_SetDebugOptions(
    WDC_DBG_OPTIONS dbgOptions,
    const CHAR *sDbgFile);
```

Parameters

Name	Type	Input/Output
dbgOptions	WDC_DBG_OPTIONS	Input
sDbgFile	const CHAR*	Input

Description

Name	Description
dbgOptions	A bit mask of flags indicating the desired debug settings – see `WDC_DBG_OPTIONS` [B.3.1.8]. If this parameter is set to zero, the default debug options will be used – see `WDC_DBG_DEFAULT` [B.3.1.8].
sDbgFile	WDC debug output file. This parameter is relevant only if the `WDC_DBG_OUT_FILE` flag is set in the debug options (`dbgOptions`) (either directly or via one of the convenience debug options combinations – see `WDC_DBG_OPTIONS` [B.3.1.8]). If the `WDC_DBG_OUT_FILE` debug flag is set and `sDbgFile` is `NULL`, WDC debug messages will be logged to the default debug file – **stderr**.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.53. WDC_Err()

Purpose

Displays debug error messages according to the WDC debug options – see `WDC_DBG_OPTIONS` [B.3.1.8] and `WDC_SetDebugOptions()` [B.3.52].

Prototype

```
void DLLCALLCONV WDC_Err(
    const CHAR *format
    [, argument] ...);
```

Parameters

Name	Type	Input/Output
format	const CHAR*	Input
argument		Input

Description

Name	Description
format	Format-control string, which contains the error message to display. The string is limited to 256 characters (CHAR)
argument	Optional arguments for the format string

Return Value

None

B.3.54. WDC_Trace()

Purpose

Displays debug trace messages according to the WDC debug options – see `WDC_DBG_OPTIONS` [B.3.1.8] and `WDC_SetDebugOptions`() [B.3.52].

Prototype

```
void DLLCALLCONV WDC_Trace(
    const CHAR *format
    [, argument] ...);
```

Parameters

Name	Type	Input/Output
format	const CHAR*	Input
argument		Input

Description

Name	Description
format	Format-control string, which contains the trace message to display. The string is limited to 256 characters (CHAR)
argument	Optional arguments for the format string

Return Value

None

B.3.55. WDC_GetWDHandle()

Purpose

Returns a handle to WinDriver's kernel module, which is required by the basic `WD_xxx` WinDriver PCI/PCMCIA/ISA API, described in the **WinDriver PCI Low-Level API Reference** (see Remarks below).

Prototype

```
HANDLE DLLCALLCONV WDC_GetWDHandle(void);
```

Return Value

Returns a handle to WinDriver's kernel module, or `INVALID_HANDLE_VALUE` in case of a failure

Remarks

- When using only the WDC API, you do not need to get a handle to WinDriver, since the WDC library encapsulates this for you. This function enables you to get the WinDriver handles used by the WDC library so you can pass it to low-level `WD_xxx` API, if such APIs are used from your code. In such cases, take care **not** to close the handle you received (using `WD_Close`()). The handle will be closed by the WDC library when it is closed, using `WDC_DriverClose`() [B.3.3]. The low-level `WD_xxx` API is described in the **WinDriver PCI Low-Level API Reference**.

B.3.56. WDC_GetDevContext()

Purpose

Returns the device's user context information.

Prototype

```
PVOID DLLCALLCONV WDC_GetDevContext(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])

Return Value

Returns a pointer to the device's user context, or `NULL` if no context has been set.

B.3.57. WDC_GetBusType()

Purpose

Returns the device's bus type: `WD_BUS_PCI`, `WD_BUS_PCMCIA`, `WD_BUS_ISA` or `WD_BUS_UNKNOWN`.

Prototype

```
WD_BUS_TYPE DLLCALLCONV WDC_GetBusType(WDC_DEVICE_HANDLE hDev);
```

Parameters

Name	Type	Input/Output
hDev	WDC_DEVICE_HANDLE	Input

Description

Name	Description
hDev	Handle to a WDC device, returned by `WDC_xxxDeviceOpen()` (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12])

Return Value

Returns the device's bus type [B.5.1].

B.3.58. WDC_Sleep()

Purpose

Delays execution for the specified duration of time (in microseconds).
By default the function performs a busy sleep (consumes CPU cycles).

Prototype

```
DWORD DLLCALLCONV WDC_Sleep(
    DWORD dwMicroSecs,
    WDC_SLEEP_OPTIONS options);
```

Parameters

Name	Type	Input/Output
dwMicroSecs	DWORD	Input
options	WDC_SLEEP_OPTIONS	Input

Description

Name	Description
dwMicroSecs	The number of microseconds to sleep
options	Sleep options [B.3.1.7]

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.3.59. WDC_Version()

Purpose

Returns the version number of the WinDriver kernel module used by the WDC library.

Prototype

```
DWORD DLLCALLCONV WDC_Version(
    CHAR *sVersion,
    DWORD *pdwVersion);
```

Parameters

Name	Type	Input/Output
sVersion	CHAR*	Output
pdwVersion	DWORD*	Output

Description

Name	Description
sVersion	Pointer to a pre-allocated buffer to be filled by the function with the driver's version information string. The size of the version string buffer must be at least 128 bytes (characters).
pdwVersion	Pointer to a value indicating the version number of the WinDriver kernel module used by the WDC library

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.4. WDC Low Level API

This section described the WDC types and preprocessor definitions defined in the **WinDriver/include/wdc_defs.h** header file.

B.4.1. WDC_ID_U Union

WDC device ID information union (used for PCI and PCMCIA devices).

Field	Type	Description
pciId	WD_PCI_ID	PCI device ID information structure [B.5.6]
pcmciaId	WD_PCMCIA_ID	PCMCIA device ID information structure [B.5.7]

B.4.2. WDC_ADDR_DESC Structure

PCI/PCMCIA/ISA device memory or I/O address space information structure.

Field	Type	Description
dwAddrSpace	DWORD	The address space number
fIsMemory	BOOL	• **TRUE**: memory address space. • **FALSE**: I/O address space.

Field	Type	Description
dwItemIndex	DWORD	The index of the `WD_ITEMS` structure [B.5.10] for the address space, which is retrieved and stored by `WDC_xxxDeviceOpen`() in the `cardReg.Card.Item` array of the relevant WDC device information structure [B.4.3]
dwBytes	DWORD	The address space's size (in bytes)
kptAddr	KPTR	The kernel-mode mapping of the address space's physical base address. This address is used by the WDC API for accessing a memory or I/O region using the low-level `WD_Transfer`() or `WD_MultiTransfer`() APIs (described in the **WinDriver PCI Low-Level API Reference**), or when accessing memory address directly in the kernel.
dwUserDirectMemAddr	UPTR	The user-mode mapping of a memory address space's physical base address. This address is used for accessing memory addresses directly from the user mode

B.4.3. WDC_DEVICE Structure

PCI/PCMCIA/ISA device information structure.
The `WDC_xxxDeviceOpen`() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) allocate and return device structures of this type.

Field	Type	Description
id	WDC_ID_U	Device ID information union (relevant for PCI and PCMCIA devices) – see [B.4.1]
slot	WDC_SLOT_U	Device location information structure – see description of `WDC_SLOT_U` in Section B.3.1.9
dwNumAddrSpaces	DWORD	Number of address spaces found on the device
pAddrDesc	WDC_ADDR_DESC*	Array of memory and I/IO address spaces information structures [B.4.2]
cardReg	WD_CARD_REGISTER	WinDriver device resources information structure, returned by the low-level `WD_CardRegister`() function (see the **WinDriver PCI Low-Level API Reference**),

Field	Type	Description
		which is called by the `WDC_xxxDeviceOpen()` functions
kerPlug	WD_KERNEL_PLUGIN	Kernel PlugIn driver information structure [B.7.1]. This structure is filled by the functions used to open a handle to a Kernel PlugIn for a `WDC_DEVICE` [12.4] – either `WDC_KernelPlugInOpen()` [B.3.17], or one of the `WDC_xxxDeviceOpen()` functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) when called with the name of a Kernel PlugIn driver – and is maintained by the WDC library. If no Kernel PlugIn handle was opened for the device, this structure is not used.
Int	WD_INTERRUPT	Interrupt information structure. This structure is filled by the `WDC_xxxDeviceOpen()` functions for devices that have interrupts, and is maintained by the WDC library.
hIntThread	DWORD	Handle to the interrupt thread that is spawn when interrupts are enabled. This handle is passed by WDC to the low-level WinDriver interrupt APIs. When using the WDC API you do not need to access this handle directly.
Event	WD_EVENT	WinDriver Plug-and-Play and power management events information structure – see `EventRegister()` description in the **WinDriver PCI Low-Level API Reference** for details.

Field	Type	Description
hEvent	HANDLE	Handle used by the WinDriver `EventRegister()` / `EventUnregister()` functions (see the **WinDriver PCI Low-Level API Reference**) When using the WDC API you do not need to access this handle directly.
pCtx	PVOID	Device context information. This information is received as a parameter by the `WDC_xxxDeviceOpen()` functions and stored in the device structure for future use by the calling application (optional)

B.4.4. PWDC_DEVICE

Pointer to a `WDC_DEVICE` structure [B.4.3].

```
typedef WDC_DEVICE *PWDC_DEVICE
```

B.4.5. WDC_MEM_DIRECT_ADDR Macro

Purpose

Utility macro that returns a pointer that can be used for direct access to a specified memory address space from the context of the calling process.

Prototype

```
WDC_MEM_DIRECT_ADDR(pAddrDesc)
```

Parameters

Name	Type	Input/Output
pAddrDesc	WDC_ADDR_DESC*	Input

Description

Name	Description
pAddrDesc	Pointer to a WDC memory address space information structure [B.4.2]

Return Value

When called from the user mode, returns the user-mode mapping of the physical memory address (`pAddrDesc->dwUserDirectMemAddr`);
When called from the kernel mode, returns the kernel-mode mapping of the physical memory address (`pAddrDesc->kptAddr`).
The returned pointer can be used for accessing the memory directly from the user mode or kernel mode, respectively.

B.4.6. WDC_ADDR_IS_MEM Macro

Purpose

Utility macro that checks if a given address space is a memory or I/O address space.

Prototype

```
WDC_ADDR_IS_MEM(pAddrDesc)
```

Parameters

Name	Type	Input/Output
pAddrDesc	WDC_ADDR_DESC*	Input

Description

Name	Description
pAddrDesc	Pointer to a WDC memory address space information structure [B.4.2]

Return Value

Returns `pAddrDesc->fIsMemory`, which is set to `TRUE` for a memory address space and to `FALSE` otherwise.

B.4.7. WDC_GET_ADDR_DESC Macro

Purpose

Utility macro that retrieves a WDC address space information structure (`WDC_ADDR_DESC` [B.4.2]), which complies to the specified address space number.

Prototype

```
WDC_GET_ADDR_DESC(
    pDev,
    dwAddrSpace)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input
dwAddrSpace	DWORD	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.4]
dwAddrSpace	Address space number

Return Value

Returns a pointer to the device's address information structure (`WDC_ADDR_DESC` [B.4.2]) for the specified address space number – `pDev->pAddrDesc[dwAddrSpace]`.

B.4.8. WDC_GET_ENABLED_INT_TYPE Macro

Purpose

Utility macro for retrieving the value of a WDC device's **`dwEnabledIntType`** `WD_INTERRUPT` field. This field is updated by `WDC_IntEnable`() [B.3.46] to indicate the interrupt type enabled for the device, as detailed in the description of the macro's return value below.

Prototype

```
WDC_GET_ENABLED_INT_TYPE(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.4]

Return Value

Returns the interrupt type enabled for the device:

- **`INTERRUPT_MESSAGE_X`**: Extended Message-Signaled Interrupts (MSI-X).
- **`INTERRUPT_MESSAGE`**: Message-Signaled Interrupts (MSI).
- **`INTERRUPT_LEVEL_SENSITIVE`**: Legacy level-sensitive interrupts.
- **`INTERRUPT_LATCHED`**: Legacy edge-triggered interrupts.
  The value of this flag is zero and it is applicable only when no other interrupt flag is set.

Remarks

- The Windows and Mac OS X APIs do not distinguish between MSI and MSI-X; therefore, on these OSs the WinDriver functions set the **`INTERRUPT_MESSAGE`** flag for both MSI and MSI-X.
- Call this macro only after calling `WDC_IntEnable`() [B.3.46] to enable interrupts on your PCI card.
- This macro is normally relevant only in the case of PCI devices that support more than one type of interrupt.
- You can pass the returned value to the `WDC_INT_IS_MSI` macro to check if MSI or MSI-X was enabled [B.4.10].

B.4.9. WDC_GET_INT_OPTIONS Macro

Purpose

Utility macro for retrieving the value of a WDC device's interrupt options, which indicate the types of interrupts supported by the device, as detailed in the description of the macro's return value below.

Prototype

```
WDC_GET_INT_OPTIONS(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.4]

Return Value

Returns a bit-mask indicating the types of interrupts supported by the device:

- **`INTERRUPT_MESSAGE_X`**: Extended Message-Signaled Interrupts (MSI-X).
- **`INTERRUPT_MESSAGE`**: Message-Signaled Interrupts (MSI).
- **`INTERRUPT_LEVEL_SENSITIVE`**: Legacy level-sensitive interrupts.
- **`INTERRUPT_LATCHED`**: Legacy edge-triggered interrupts.
  The value of this flag is zero and it is applicable only when no other interrupt flag is set.

Remarks

- You can pass the returned options to the `WDC_INT_IS_MSI` macro to check whether they include the `INTERRUPT_MESSAGE` (MSI) and/or `INTERRUPT_MESSAGE_X` (MSI-X) flags [B.4.10].

B.4.10. WDC_INT_IS_MSI Macro

Purpose

Utility macro that checks whether a given interrupt type bit-mask contains the Message-Signaled Interrupts (MSI) or Extended Message-Signaled Interrupts (MSI-X) interrupt type flags.

Prototype

```
WDC_INT_IS_MSI(dwIntType)
```

Parameters

Name	Type	Input/Output
dwIntType	DWORD	Input

Description

Name	Description
dwIntType	Interrupt types bit-mask

Return Value

Returns TRUE if the provided interrupt type bit-mask includes the **INTERRUPT_MESSAGE** (MSI) and/or **INTERRUPT_MESSAGE_X** (MSI-X) flags; otherwise returns FALSE.

B.4.11. WDC_GET_ENABLED_INT_LAST_MSG Macro

Purpose

Utility macro that retrieves the message data of the last received interrupt for the Message-Signaled Interrupts (MSI) / Extended Message-Signaled Interrupts (MSI-X) enabled for the device (on Linux, Mac OS X, and Windows Vista and higher).

Prototype

```
WDC_GET_ENABLED_INT_LAST_MSG(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.4]

Return Value

If MSI or MSI-X was enabled for the given device, the macro returns the message data of the last message received for the device's interrupt; otherwise returns zero.

B.4.12. WDC_IS_KP Macro

Purpose

Utility macro that checks whether a WDC device uses a Kernel PlugIn driver.

Prototype

```
WDC_IS_KP(pDev)
```

Parameters

Name	Type	Input/Output
pDev	PWDC_DEVICE	Input

Description

Name	Description
pDev	Pointer to a WDC device information structure [B.4.4]

Return Value

Returns TRUE if the device uses a Kernel PlugIn driver; otherwise returns FALSE.

B.5. WD_xxx Structures, Types and General Definitions

This section describes basic WD_xxx structures and types, which are used by the WDC_xxx APIs. The APIs described in this section are defined in the **WinDriver/include/windrvr.h** header file.

B.5.1. WD_BUS_TYPE Enumeration

Bus types enumeration.

Enum Value	Description
WD_BUS_USB	Universal Serial Bus (USB)
WD_BUS_UNKNOWN	Unknown bus
WD_BUS_ISA	ISA bus
WD_BUS_EISA	EISA (ISA Plug-and-Play) bus
WD_BUS_PCI	PCI bus
WD_BUS_PCMCIA	PCMCIA bus

B.5.2. ITEM_TYPE Enumeration

Enumeration of card item types.

Enum Value	Description
ITEM_NONE	Unknown item type
ITEM_INTERRUPT	Interrupt item
ITEM_MEMORY	Memory item
ITEM_IO	I/O item
ITEM_BUS	Bus item

B.5.3. WD_PCMCIA_ACC_SPEED Enumeration

Enumeration of PCMCIA bus-access speeds.

Enum Value	Description
WD_PCMCIA_ACC_SPEED_DEFAULT	Use the default PCMCIA bus access speed
WD_PCMCIA_ACC_SPEED_250NS	250 ns
WD_PCMCIA_ACC_SPEED_200NS	200 ns
WD_PCMCIA_ACC_SPEED_150NS	150 ns
WD_PCMCIA_ACC_SPEED_1000NS	100 ns

B.5.4. WD_PCMCIA_ACC_WIDTH Enumeration

Enumeration of PCMCIA bus width.

Enum Value	Description
WD_PCMCIA_ACC_WIDTH_DEFAULT	Use the default PCMCIA bus width
WD_PCMCIA_ACC_WIDTH_8BIT	8-bit
WD_PCMCIA_ACC_WIDTH_16BIT	16-bit

B.5.5. WD_PCMCIA_VPP Enumeration

Enumeration of the PCMCIA controller's Voltage Power Pin (Vpp) power levels.

Enum Value	Description
WD_PCMCIA_VPP_DEFAULT	Use the default power level of the PCMCIA Vpp pin
WD_PCMCIA_VPP_OFF	Set the voltage on the Vpp pin to zero (disable)
WD_PCMCIA_VPP_ON	Set the voltage on the Vpp pin to 12V (enable)

© Jungo Ltd. 2005–2011

Enum Value	Description
WD_PCMCIA_VPP_AS_VSS	Set the voltage on the Vpp pin to equal that of the Vcc pin

B.5.6. WD_PCI_ID Structure

PCI device identification information structure.

Field	Type	Description
dwVendorId	DWORD	Vendor ID
dwDeviceId	DWORD	Device ID

B.5.7. WD_PCMCIA_ID Structure

PCMCIA device identification information structure.

Field	Type	Description
wManufacturerId	WORD	Manufacturer ID
wCardId	WORD	Device ID

B.5.8. WD_PCI_SLOT Structure

PCI device location information structure.

Field	Type	Description
dwBus	DWORD	PCI Bus number (0 based)
dwSlot	DWORD	Slot number (0 based)
dwFunction	DWORD	Function number (0 based)

B.5.9. WD_PCMCIA_SLOT Structure

PCMCIA device location information structure.

Field	Type	Description
uBus	BYTE	PCMCIA Bus number (0 based)
uSocket	BYTE	Socket number (0 based)
uFunction	BYTE	Function number (0 based)

B.5.10. WD_ITEMS Structure

Card resources information structure.

Field	Type	Description
item	DWORD	Item type – see the `ITEM_TYPE` enumeration [B.5.2]. This field is updated by the `WDC_XXXGetDeviceInfo`() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level `WD_PciGetCardInfo`() and `WD_PcmciaGetCardInfo`() functions (see the **WinDriver PCI Low-Level API Reference**).
fNotSharable	DWORD	• **1** – Non-sharable resource; should be locked for exclusive use • **0** – Sharable resource This field is updated by the `WDC_xxxGetDeviceInfo`() functions (PCI [B.3.8] / PCMCIA [B.3.9]) or the low-level `WD_PciGetCardInfo`() and `WD_PcmciaGetCardInfo`() functions, and can be modified manually before registering the resources using the `WDC_xxxDeviceOpen`() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) or the low-level `WD_CardRegister`() function; (the low-level functions are documented in the **WinDriver PCI Low-Level API Reference**).
dwOptions	DWORD	A bit-mask of item registration flags, applicable when calling one of the `WDC_xxxDeviceOpen`() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) or the low-level `WD_CardRegister`() function (see the **WinDriver PCI Low-Level API Reference**). The mask can consist of a combination of any of the of the following `WD_ITEM_OPTIONS` enumeration values: • **`WD_ITEM_DO_NOT_MAP_KERNEL`**: This flag instructs the function to avoid mapping a memory address range to the kernel virtual address space and map the memory only to the user-mode virtual address space. For more information, refer to Remark 2 in the documentation of

Field	Type	Description
		WDC_PciDeviceOpen() [B.3.10]; (a similar remark is found in the documentation of the other device-open functions). NOTE: This flag is applicable only to memory items. • **WD_ITEM_ALLOW_CACHE** (Windows and Windows CE): Map the item's physical memory (I.Mem.dwPhysicalAddr) as cached. NOTE: This flag is applicable only to memory items that pertain to the host's RAM, as opposed to local memory on the card.
I	union	Union of resources data, based on the item's type (**item**)
• Mem	struct	Memory item data (item = ITEM_MEMORY)
* dwPhysicalAddr	DWORD	First address of the physical memory range. This field is updated by the WDC_XXXGetDeviceInfo() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level WD_PciGetCardInfo() and WD_PcmciaGetCardInfo() functions (see the **WinDriver PCI Low-Level API Reference**).
* dwBytes	DWORD	Length (in bytes) of the memory range. This field is updated by the WDC_XXXGetDeviceInfo() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level WD_PciGetCardInfo() and WD_PcmciaGetCardInfo() functions (see the **WinDriver PCI Low-Level API Reference**).
* dwTransAddr	DWORD	Kernel-mode mapping of the memory range's physical base address (**dwPhysicalAddr**). This field is updated by WD_CardRegister() (see the **WinDriver PCI Low-Level API Reference**), which is called from the WDC_xxxDeviceOpen() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]).

Field	Type	Description
* dwUserDirectAddr	DWORD	User-mode mapping of the memory range's physical base address (**dwPhysicalAddr**). This field is updated by WD_CardRegister() (see the **WinDriver PCI Low-Level API Reference**), which is called from the WDC_xxxDeviceOpen() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]).
* dwCpuPhysicalAddr	DWORD	Translation of the card's physical memory base address (**dwPhysicalAddr**) from bus-specific values to CPU values. This field is updated by WD_CardRegister() (see the **WinDriver PCI Low-Level API Reference**), which is called from the WDC_xxxDeviceOpen() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]).
* dwBar	DWORD	Base Address Register (BAR) number. This field is updated by the WDC_XXXGetDeviceInfo() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level WD_PciGetCardInfo() and WD_PcmciaGetCardInfo() functions (see the **WinDriver PCI Low-Level API Reference**).
• IO	struct	I/O item data (item = ITEM_IO)
* dwAddr	DWORD	First address of the I/O range. This field is updated by the WDC_XXXGetDeviceInfo() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level WD_PciGetCardInfo() and WD_PcmciaGetCardInfo() functions (see the **WinDriver PCI Low-Level API Reference**).
* dwBytes	DWORD	Length (in bytes) of the I/O range. This field is updated by the WDC_XXXGetDeviceInfo() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level WD_PciGetCardInfo() and WD_PcmciaGetCardInfo() functions (see the **WinDriver PCI Low-Level API Reference**).

Field	Type	Description
* dwBar	DWORD	Base Address Register (BAR) number. This field is updated by the `WDC_XXXGetDeviceInfo`() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level `WD_PciGetCardInfo`() and `WD_PcmciaGetCardInfo`() functions (see the **WinDriver PCI Low-Level API Reference**).
• Int	struct	Interrupt item data (`item = ITEM_INTERRUPT`)
* dwInterrupt	DWORD	Physical interrupt request (IRQ) number. This field is updated by the `WDC_XXXGetDeviceInfo`() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level `WD_PciGetCardInfo`() and `WD_PcmciaGetCardInfo`() functions (see the **WinDriver PCI Low-Level API Reference**).
* dwOptions	DWORD	Interrupt bit-mask, which can consist of a combination of any of the following flags: **Interrupt type flags:** • **`INTERRUPT_MESSAGE_X`** – Indicates that the hardware supports Extended Message-Signaled Interrupts (MSI-X). This option is applicable only to PCI cards on Linux – see information in Section 9.2.3. • **`INTERRUPT_MESSAGE`** – On Linux, indicates that the hardware supports Message-Signaled Interrupts (MSI). On Windows and Mac OS X, indicates that the hardware supports MSI or MSI-X. This option is applicable only to PCI cards on Linux, Mac OS X, and Windows Vista and higher – see information in Section 9.2.3. • **`INTERRUPT_LEVEL_SENSITIVE`** – Indicates that the hardware supports level-sensitive interrupts. • **`INTERRUPT_LATCHED`** – indicates that the device supports legacy edge-triggered interrupts. The value of this flag is zero, therefore it is applicable only when no other interrupt flag is set. **NOTE:** For Plug-and-Play hardware (PCI/PCMCIA), use WinDriver's

Field	Type	Description
		`WDC_PciGetDeviceInfo`() [B.3.8] (PCI) or `WDC_PcmciaGetDeviceInfo`() [B.3.9] (PCMCIA) function (or the low-level `WD_PciGetCardInfo`() or `WD_PcmciaGetCardInfo`() function) to retrieve the Plug-and-Play hardware information, including the supported interrupt types. For non-Plug-and-Play hardware, the relevant interrupt type flag (normally – `INTERRUPT_LATCHED`) should be set by the user in the call to `WDC_IsaDeviceOpen`() or to the low-level `WD_CardRegister`() function. **Miscellaneous interrupt options:** • **`INTERRUPT_CE_INT_ID`** – On Windows CE (unlike other operating systems), there is an abstraction of the physical interrupt number to a logical one. Setting this flag within the resources information passed to the relevant `WDC_xxxDeviceOpen`() function will instruct WinDriver to refer to the **`dwInterrupt`** value as a logical interrupt number and convert it to a physical interrupt number.
* hInterrupt	DWORD	Handle to an internal WinDriver interrupt structure, required by the low-level `WD_xxx`() WinDriver interrupt APIs (see the **WinDriver PCI Low-Level API Reference**). This field is updated by `WD_CardRegister`() (see the **WinDriver PCI Low-Level API Reference**), which is called from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]).
• Bus	WD_BUS	Bus item data (`item = ITEM_BUS`)
* dwBusType	WD_BUS_TYPE	Device's bus type – see the `WD_BUS_TYPE` enumeration [B.5.1]
* dwBusNum	DWORD	Bus Number

Field	Type	Description
* dwSlotFunc	DWORD	Slot/socket and function information for the device: The lower three bits represent the function number and the remaining bits represent the slot/socket number. For example: a value of 0x80 (<=> 10000000 binary) corresponds to a function number of 0 (lower 3 bits: 000) and a slot/socket number of 0x10 (remaining bits: 10000). This field is updated by the `WDC_XXXGetDeviceInfo`() functions (PCI: [B.3.8]; PCMCIA: [B.3.9]) or the low-level `WD_PciGetCardInfo`() and `WD_PcmciaGetCardInfo`() functions (see the **WinDriver PCI Low-Level API Reference**).
Val	struct	Reserved for internal use

B.5.11. WD_CARD Structure

Card information structure.

Field	Type	Description
dwItems	DWORD	Number of items (resources) on the card
Item	WD_ITEMS [WD_CARD_ITEMS]	Array of card resources (items) information structures [B.5.10]

B.5.12. WD_PCI_CARD_INFO Structure

PCI card information structure.

Field	Type	Description
pciSlot	WD_PCI_SLOT	PCI device location information structure [B.5.8], which can be acquired by calling `WDC_PciScanDevices`() [B.3.4] (or the low-level `WD_PciScanCards`() function – see the **WinDriver PCI Low-Level API Reference**)
Card	WD_CARD	Card information structure [B.5.11]

B.5.13. WD_PCMCIA_CARD_INFO Structure

PCMCIA card information structure.

Field	Type	Description
pcmciaSlot	WD_PCMCIA_SLOT	PCMCIA device location information structure [B.5.9], which can be acquired by calling `WDC_PcmciaScanDevices`() [B.3.7] (or the low-level `WD_PcmciaScanCards`() function – see the **WinDriver PCI Low-Level API Reference**)
Card	WD_CARD	Card information structure [B.5.11]
cVersion	CHAR [WD_PCMCIA_VERSION_LEN]	Version string
cManufacturer	CHAR[WD_PCMCIA_ MANUFACTURER_LEN]	Manufacturer string
cProductName	CHAR[WD_PCMCIA_ PRODUCTNAME_LEN]	Product string
wManufacturerId	WORD	Manufacturer ID
wCardId	WORD	Device ID
wFuncId	WORD	Function ID

B.5.14. WD_DMA Structure

Direct Memory Access (DMA) information structure.

Field	Type	Description
hDma	DWORD	DMA buffer handle (or 0 for a failed allocation). This handle is returned from `WDC_DMAContigBufLock()` [B.3.39] and `WDC_DMASGBufLock()` [B.3.40] (or from the low-level `WD_DMALock()` function – see the **WinDriver PCI Low-Level API Reference**)
pUserAddr	PVOID	User-mode mapped address of the DMA buffer. This mapping is returned from `WDC_DMAContigBufLock()` [B.3.39] and `WDC_DMASGBufLock()` [B.3.40] (in this function the `pBuf` user-mode buffer provided by the caller is used), or from the low-level `WD_DMALock()` function (see the **WinDriver PCI Low-Level API Reference**). Note: if the `DMA_KERNEL_ONLY` flag was set in the DMA options bit-mask field (**`dwOptions`**), this field is not updated.
pKernelAddr	KPTR	Kernel-mode mapped address of the DMA buffer. This mapping is returned from `WDC_DMAContigBufLock()` [B.3.39] and `WDC_DMASGBufLock()` [B.3.40] (on Windows 7 / Vista / Server 2008 / Server 2003 / XP), or from the low-level `WD_DMALock()` function (for Contiguous Buffer DMA and for Scatter/Gather DMA on Windows 7 / Vista / Server 2008 / Server 2003 / XP – see the **WinDriver PCI Low-Level API Reference**)
dwBytes	DWORD	The size of the DMA buffer (in bytes)
dwOptions	DWORD	DMA options bit-mask, which can consist of a combination of any of the enumeration values listed below. **NOTE:** Options that are also applicable to the `WDC_DMASGBufLock()` and `WDC_DMAContigBufLock()` functions (according to the descriptions below) should be set within these functions' `dwOptions` parameter. The `dwOptions` field of the `WD_DMA` structure returned by these functions will be updated accordingly. DMA flags:

Field	Type	Description
		• **DMA_FROM_DEVICE**: Synchronize the DMA buffer for transfers from the device to memory. • **DMA_TO_DEVICE**: Synchronize the DMA buffer for transfers from memory to the device. • **DMA_TO_FROM_DEVICE**: Synchronize the DMA buffer for transfers in both directions – i.e., from the device to memory and from memory to the device (<=> DMA_FROM_DEVICE | DMA_TO_DEVICE). • **DMA_KERNEL_BUFFER_ALLOC**: Allocate a contiguous DMA buffer in the physical memory. The default behavior (when this flag is not set) is to allocate a Scatter/Gather DMA buffer. Set this flag when calling the low-level WD_DMALock() function to allocate a Contiguous DMA buffer (see the **WinDriver PCI Low-Level API Reference**). When using the WDC APIs there is no need to set this flag, since WDC_DMAContigBufLock() [B.3.39] sets it automatically, and WDC_DMASGBufLock() [B.3.40] is used to allocate Scatter/Gather DMA buffers, for which this flag is not applicable. • **DMA_KBUF_BELOW_16M**: Allocate the physical DMA buffer within the first 16MB of the main memory. This flag is applicable only to Contiguous Buffer DMA – i.e., when calling WDC_DMAContigBufLock() [B.3.39] or when calling the low-level WD_DMALock() flag with the DMA_KERNEL_BUFFER_ALLOC flag (see the **WinDriver PCI Low-Level API Reference**). • **DMA_LARGE_BUFFER**: Enable locking of a large DMA buffer – dwBytes > 1MB. This flag is applicable only to Scatter/Gather DMA. Set this flag when calling the low-level WD_DMALock() function to allocate a large DMA buffer (see the **WinDriver PCI Low-Level API Reference**). When using the WDC APIs there is no need to set this flag, since

Field	Type	Description
		WDC_DMASGBufLock() [B.3.40] sets it automatically when called to allocate a large DMA buffer, and WDC_DMAContigBufLock() [B.3.39] is used to allocate Contiguous DMA buffers, for which this flag is not applicable. • **DMA_ALLOW_CACHE**: Allow caching of the DMA buffer. • **DMA_KERNEL_ONLY_MAP**: Do not map the allocated DMA buffer to the user mode (i.e., map it to kernel-mode only). This flag is applicable only in cases where the DMA_KERNEL_BUFFER_ALLOC flag is applicable – see above. • **DMA_ALLOW_64BIT_ADDRESS**: Allow allocation of 64-bit DMA addresses. This flag is supported on Windows, Mac OS X, and Linux.
dwPages	DWORD	Number of physical memory blocks used for the allocated buffer. For Contiguous Buffer DMA this field is always set to 1.
hCard	DWORD	Low-level WinDriver card handle, which is acquired by WDC_xxxDeviceOpen() (by calling WD_CardRegister() – see the **WinDriver PCI Low-Level API Reference**) and stored in the WDC device structure
Page	WD_DMA_PAGE [WD_DMA_PAGES]	Array of physical memory pages information structures. For contiguous buffer DMA this array always holds only one element (see dwPages).
• pPhysicalAddr	KPTR	The page's physical address
• dwBytes	DWORD	The page's size (in bytes)

B.5.15. WD_TRANSFER Structure

Memory/IO read/write transfer command information structure.

Field	Type	Description
cmdTrans	DWORD	A value indicating the type of transfer to perform – refer to the definition of the `WD_TRANSFER_CMD` enumeration in **windrvr.h**. The transfer command can be of either of the following types: • A read/write transfer command that conforms to the following format: **`<dir><p>_[S]<size>`** Explanation: **`<dir>`**: **`R`** for read, **`W`** for write **`<p>`**: **`P`** for I/O, **`M`** for memory **`<S>`**: signifies a string (block) transfer, as opposed to a single transfer **`<size>`**: BYTE, WORD, DWORD or QWORD • **`CMD_MASK`**: This command is applicable when passing interrupt transfer commands to the interrupt enable functions (`WDC_IntEnable`() [B.3.46] or the low-level `InterruptEnable`() or `WD_IntEnable`() functions – see the **WinDriver PCI Low-Level API Reference**). `CMD_MASK` is an interrupt mask command for determining the source of the interrupt: When this command is set, upon the arrival of an interrupt in the kernel WinDriver masks the value of the previous read command in the `WD_TRANSFER` commands array with the mask that is set in the relevant `Data` field union member of the mask transfer command. For example, for a `pTransCmdsWD_TRANSFER` array, if `pTransCmds[i-1].cmdTrans` is `RM_BYTE`, WinDriver performs the following mask: `pTransCmds[i-1].Data.Byte & pTransCmds[i].Data.Byte` . If the mask is successful, the driver claims ownership of the interrupt and when the control is returned to the user mode, the interrupt handler routine that was passed to the interrupt enable function is invoked; otherwise, the driver rejects ownership of the interrupt, the interrupt handler routine is not invoked and the subsequent transfer commands in the array are not executed. (Acceptance and rejection of the interrupt is relevant only when handling legacy interrupts; since MSI/MSI-X interrupts are not shared, WinDriver will always accept control of such interrupts.) NOTE: A `CMD_MASK` command must be preceded by a read transfer command (`RM_XXX / RP_XXX`).">
dwPort	KPTR	The I/O port address or the kernel-mapped virtual memory address, which has been stored in the relevant device (`WDC_DEVICE` [B.4.3]): `dev.pAddrDesc[i].kptAddr` (where *i* is the index of the desired address space). (When using the low-level `WD_xxx`() APIs, these values are stored within the `dwAddr` (I/O) and `dwTransAddr`

Field	Type	Description
		(memory) fields of the relevant `cardReg.Card.Item[i]` item – see the **WinDriver PCI Low-Level API Reference**).
dwBytes	DWORD	The number of bytes to transfer
fAutoinc	DWORD	Relevant only for string (block) transfers: If **TRUE**, the I/O or memory port/address will be incremented after each block that is transferred; If **FALSE**, all data is transferred to/from the same port/address.
dwOptions	DWORD	Must be zero
Data	union	The data buffer for the transfer (input for write commands, output for read commands):
• Byte	BYTE	Used for 8-bit transfers
• Word	WORD	Used for 16-bit transfers
• Dword	UINT32	Used for 32-bit transfers
• Qword	UINT64	Used for 64-bit transfers
• pBuffer	PVOID	Used for string (block) transfers – a pointer to the data buffer for the transfer

B.6. Kernel PlugIn Kernel-Mode Functions

The following functions are callback functions which are implemented in your Kernel PlugIn driver, and which will be called when their calling event occurs. For example: `KP_Init` [B.6.1] is the callback function that is called when the driver is loaded. Any code that you want to execute upon loading should be in this function.

`KP_Init` [B.6.1] sets the name of the driver and the `KP_Open` [B.6.2] function(s).

`KP_Open` [B.6.2] sets the rest of the driver's callback functions.

For example:

```
kpOpenCall->funcClose = KP_Close;
    kpOpenCall->funcCall = KP_Call;
    kpOpenCall->funcIntEnable = KP_IntEnable;
    kpOpenCall->funcIntDisable = KP_IntDisable;
    kpOpenCall->funcIntAtIrql = KP_IntAtIrql;
    kpOpenCall->funcIntAtDpc = KP_IntAtDpc;
    kpOpenCall->funcIntAtIrqlMSI = KP_IntAtIrqlMSI;
    kpOpenCall->funcIntAtDpcMSI = KP_IntAtDpcMSI;
    kpOpenCall->funcEvent = KP_Event;
```

As explained in Section 11.6.2.1, it is the convention of this reference guide to mark the Kernel PlugIn callback functions as `KP_<functionality>` – e.g., `KP_Open`. However, you are free to select any name that you wish for your Kernel PlugIn callback functions, apart from `KP_Init`. The generated DriverWizard Kernel PlugIn code, for example, uses the selected driver name in the callback function names (e.g., for a <MyKP> driver it creates callbacks named `KP_MyKP_Open`, `KP_MyKP_Call`, etc.).

B.6.1. KP_Init

Purpose

Kernel PlugIn initialization function.
This function is called when the Kernel PlugIn driver is loaded.
The function sets the name of the Kernel PlugIn driver and the `KP_Open` callback function(s) [B.6.2].

Prototype

```
BOOL __cdecl KP_Init(KP_INIT *kpInit);
```

Parameters

Name	Type	Input/Output
kpInit	KP_INIT*	Output

Description

Name	Description
kpInit	Pointer to a pre-allocated Kernel PlugIn initialization information structure [B.7.4], whose fields should be updated by the function

Return Value

TRUE if successful. Otherwise FALSE.

Remarks

You must define the `KP_Init` function in your code in order to link the Kernel PlugIn driver to WinDriver. `KP_Init` is called when the driver is loaded. Any code that you want to execute upon loading should be in this function.

EXAMPLE

```
BOOL __cdecl KP_Init(KP_INIT *kpInit)
{
    /* Check if the version of the WinDriver Kernel
       PlugIn library is the same version
       as windrvr.h and wd_kp.h */
    if (kpInit->dwVerWD != WD_VER)
    {
        /* You need to recompile your Kernel PlugIn
           with the compatible version of the WinDriver
           Kernel PlugIn library, windrvr.h and wd_kp.h */
       return FALSE;
    }

    kpInit->funcOpen = KP_Open;
    kpInit->funcOpen_32_64 = KP_PCI_VIRT_Open_32_64;
    strcpy (kpInit->cDriverName, "KPDriver"); /* Up to 12 chars */

  return TRUE;
}
```

B.6.2. KP_Open

Purpose

Kernel PlugIn open function.
This function sets the rest of the Kernel PlugIn callback functions (`KP_Call` [B.6.4], `KP_IntEnable` [B.6.6], etc.) and performs any other desired initialization (such as allocating memory for the driver context and filling it with data passed from the user mode).
The returned driver context (`*ppDrvContext`) will be passed to rest of the Kernel PlugIn callback functions.

The `KP_Open` callback is called when the `WD_KernelPlugInOpen`() function (see the **WinDriver PCI Low-Level API Reference**) is called from the user mode – either directly (when using the low-level WinDriver API [B.2]), or via a call to a high-level WDC function. `WD_KernelPlugInOpen`() is called from the `WDC_KernelPlugInOpen`() [B.3.17], and from the `WDC_xxxDeviceOpen`() functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) when they are called with the name of a valid Kernel PlugIn driver (set in the `pcKPDriverName` parameter).

The `WDC_xxxDeviceOpen`() functions cannot be used to open a handle to a 64-bit Kernel PlugIn function from a 32-bit application. For this purpose, use `WDC_KernelPlugInOpen`() (or the low-level `WD_KernelPlugInOpen`() function).

The Kernel PlugIn driver can implement two types of KP_Open callback functions –

- A "standard" Kernel PlugIn open function, which is used whenever a user-mode application opens a handle to a Kernel PlugIn driver, *except* when a 32-bit applications opens a handle to a 64-bit driver.
  This callback function is set in the funcOpen field of the KP_INIT structure [B.7.4] that is passed as a parameter to KP_Init [B.6.1].

- A function that will be used when a 32-bit user-mode application opens a handle to a 64-bit Kernel PlugIn driver.
  This callback function is set in the funcOpen_32_64 field of the KP_INIT structure [B.7.4] that is passed as a parameter to KP_Init [B.6.1].

A Kernel PlugIn driver can provide either one or both of these KP_Open callbacks, depending on the target configuration(s).

The **KP_PCI** sample (**WinDriver/samples/pci_diag/kp_pci/kp_pci.c**) implements both types of KP_Open callbacks – KP_PCI_Open() (standard) and KP_PCI_Open_32_64() (for opening a handle to a 64-bit Kernel PlugIn from a 32-bit application).
The generated DriverWizard Kernel PlugIn code always implements a standard Kernel PlugIn open function – KP_XXX_Open(). When selecting the *32-bit application for a 64-bit Kernel PlugIn* DriverWizard code-generation option (see Figure 4.10), the wizard also implements a KP_XXX_Open_32_64() function, for opening a handle to a 64-bit Kernel PlugIn driver from a 32-bit application.

Prototype

```
BOOL __cdecl KP_Open(
    KP_OPEN_CALL *kpOpenCall,
    HANDLE hWD,
    PVOID pOpenData,
    PVOID *ppDrvContext);
```

Parameters

Name	Type	Input/Output
kpOpenCall	KP_OPEN_CALL	Input
hWD	HANDLE	Input
pOpenData	PVOID	Input
ppDrvContext	PVOID*	Output

Description

Name	Description
kpOpenCall	Structure to fill in the addresses of the KP_xxx callback functions [B.7.5]
hWD	The WinDriver handle that WD_KernelPlugInOpen() was called with
pOpenData	Pointer to data passed from user mode
ppDrvContext	Pointer to driver context data with which the KP_Close [B.6.3], KP_Call [B.6.4], KP_IntEnable [B.6.6] and KP_Event [B.6.5] functions will be called. Use this to keep driver-specific information that will be shared among these callbacks.

Return Value

TRUE if successful. If FALSE, the call to WD_KernelPlugInOpen() from the user mode will fail.

EXAMPLE

```
BOOL __cdecl KP_Open(KP_OPEN_CALL *kpOpenCall, HANDLE hWD,
             PVOID pOpenData, PVOID *ppDrvContext)
{
    kpOpenCall->funcClose = KP_Close;
    kpOpenCall->funcCall = KP_Call;
    kpOpenCall->funcIntEnable = KP_IntEnable;
    kpOpenCall->funcIntDisable = KP_IntDisable;
    kpOpenCall->funcIntAtIrql = KP_IntAtIrql;
    kpOpenCall->funcIntAtDpc = KP_IntAtDpc;
    kpOpenCall->funcIntAtIrqlMSI = KP_IntAtIrqlMSI;
    kpOpenCall->funcIntAtDpcMSI = KP_IntAtDpcMSI;
    kpOpenCall->funcEvent = KP_Event;

    /* You can allocate driver context memory here: */
    *ppDrvContext = malloc(sizeof(MYDRV_STRUCT));
    return *ppDrvContext!=NULL;
}
```

B.6.3. KP_Close

Purpose

Called when `WD_KernelPlugInClose()` (see the **WinDriver PCI Low-Level API Reference**) is called from user mode.
The high-level `WDC_xxxDeviceClose()` functions (PCI [B.3.13] / PCMCIA [B.3.14] / ISA [B.3.15]) automatically call `WD_KernelPlugInClose()` for devices that contain an open Kernel PlugIn handle (see Section 12.4).

This functions can be used to perform any required clean-up for the Kernel PlugIn (such as freeing memory previously allocated for the driver context, etc.).

Prototype

```
void __cdecl KP_Close(PVOID pDrvContext);
```

`KP_FUNC_CLOSE` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.6.2]

Return Value

None

EXAMPLE

```
void __cdecl KP_Close(PVOID pDrvContext)
{
   if (pDrvContext)
        free(pDrvContext); /* Free allocated driver context memory */
}
```

B.6.4. KP_Call

Purpose

Called when the user-mode application calls `WDC_CallKerPlug`() [B.3.18] (or the low-level `WD_KernelPlugInCall`() function – see the **WinDriver PCI Low-Level API Reference**).

This function is a message handler for your utility functions.

Prototype

```
void __cdecl KP_Call(
    PVOID pDrvContext,
    WD_KERNEL_PLUGIN_CALL
    *kpCall,
    BOOL fIsKernelMode);
```

`KP_FUNC_CALL` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input/Output
kpCall	WD_KERNEL_PLUGIN_CALL	
• dwMessage	DWORD	Input
• pData	PVOID	Input/Output
• dwResult	DWORD	Output
fIsKernelMode	BOOL	Input

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.6.2] and will also be passed to `KP_Close` [B.6.3], `KP_IntEnable` [B.6.6] and `KP_Event` [B.6.5]
kpCall	Structure with user-mode information received from the `WDC_CallKerPlug`() [B.3.18] (or from the low-level `WD_KernelPlugInCall`() function – see the **WinDriver PCI Low-Level API Reference**) and/or with information to return back to the user mode [B.7.3]
fIsKernelMode	This parameter is passed by the WinDriver kernel – see the fIsKernelMode remark, below.

Return Value

None

Remarks

- Calling `WDC_CallKerPlug()` [B.3.18] (or the low-level `WD_KernelPlugInCall()` function – see the **WinDriver PCI Low-Level API Reference**) in the user mode will call your `KP_Call` [B.6.4] callback function in the kernel mode. The `KP_Call` function in the Kernel PlugIn will determine which routine to execute according to the message passed to it.

- The `fIsKernelMode` parameter is passed by the WinDriver kernel to the `KP_Call` routine. The user is not required to do anything about this parameter. However, notice how this parameter is passed in the sample code to the macro `COPY_TO_USER_OR_KERNEL` – This is required for the macro to function correctly. Please refer to Section B.6.12 for more details regarding the `COPY_TO_USER_OR_KERNEL` and `COPY_FROM_USER_OR_KERNEL` macros.

EXAMPLE

```
void __cdecl KP_Call(PVOID pDrvContext,
   WD_KERNEL_PLUGIN_CALL *kpCall, BOOL fIsKernelMode)
{
    kpCall->dwResult = MY_DRV_OK;
    switch (kpCall->dwMessage)
    {
        /* In this sample we implement a GetVersion message */
        case MY_DRV_MSG_VERSION:
            {
              DWORD dwVer = 100;
              MY_DRV_VERSION *ver = (MY_DRV_VERSION *)kpCall->pData;
              COPY_TO_USER_OR_KERNEL(&ver->dwVer, &dwVer,
                  sizeof(DWORD), fIsKernelMode);
              COPY_TO_USER_OR_KERNEL(ver->cVer, "My Driver V1.00",
                  sizeof("My Driver V1.00")+1, fIsKernelMode);

              kpCall->dwResult = MY_DRV_OK;
            }
            break;
        /* You can implement other messages here */
        default:
            kpCall->dwResult = MY_DRV_NO_IMPL_MESSAGE;
    }
}
```

B.6.5. KP_Event

Purpose

Called when a Plug-and-Play or power management event for the device is received, provided the user-mode application first called `WDC_EventRegister()` [B.3.49] with `fUseKP = TRUE` (or the low-level `EventRegister()` function with a Kernel PlugIn handle – see **WinDriver PCI Low-Level API Reference**) (see the Remarks below).

Prototype

```
BOOL __cdecl KP_Event(
    PVOID pDrvContext,
    WD_EVENT *wd_event);
```

`KP_FUNC_EVENT` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input/Output
wd_event	WD_EVENT*	Input

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.6.2] and will also be passed to `KP_Close` [B.6.3], `KP_IntEnable` [B.6.6] and `KP_Call` [B.6.4]
wd_event	Pointer to the PnP/power management event information received from the user mode

Return Value

`TRUE` in order to notify the user about the event.

Remarks

`KP_Event` will be called if the user mode process called `WDC_EventRegister()` [B.3.49] with `fUseKP= TRUE` (or of the low-level `EventRegister()` function was called with a Kernel PlugIn handle – see the **WinDriver PCI Low-Level API Reference**).

EXAMPLE

```
BOOL __cdecl KP_Event(PVOID pDrvContext, WD_EVENT *wd_event)
{
    /* Handle the event here */
    return TRUE; /* Return TRUE to notify the user about the event */
}
```

B.6.6. KP_IntEnable

Purpose

Called when `WD_IntEnable`() (see **WinDriver PCI Low-Level API Reference**) is called from the user mode with a Kernel PlugIn handle.
`WD_IntEnable`() is called automatically from `WDC_IntEnable`() [B.3.46] and `InterruptEnable`() (see **WinDriver PCI Low-Level API Reference**).

The interrupt context that is set by this function (`*ppIntContext`) will be passed to the rest of the Kernel PlugIn interrupt functions.

Prototype

```
BOOL __cdecl KP_IntEnable (
    PVOID pDrvContext,
    WD_KERNEL_PLUGIN_CALL *kpCall,
    PVOID *ppIntContext);
```

`KP_FUNC_INT_ENABLE` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pDrvContext	PVOID	Input/Output
kpCall	WD_KERNEL_PLUGIN_CALL	Input
• dwMessage	DWORD	Input
• pData	PVOID	Input/Output
• dwResult	DWORD	Output
ppIntContext	PVOID*	Input/Output

Description

Name	Description
pDrvContext	Driver context data that was set by `KP_Open` [B.6.2] and will also be passed to `KP_Close` [B.6.3], `KP_Call` [B.6.4] and `KP_Event` [B.6.5]
kpCall	Structure with information from `WD_IntEnable`() [B.7.3]
ppIntContext	Pointer to interrupt context data that will be passed to `KP_IntDisable` [B.6.7] and to the Kernel PlugIn interrupt handler functions. Use this context to keep interrupt specific information.

Return Value

Returns `TRUE` if enable is successful; otherwise returns `FALSE`.

Remarks

This function should contain any initialization needed for your Kernel PlugIn interrupt handling.

EXAMPLE

```
BOOL __cdecl KP_IntEnable(PVOID pDrvContext,
     WD_KERNEL_PLUGIN_CALL *kpCall, PVOID *ppIntContext)
{
    DWORD *pIntCount;
    /* You can allocate specific memory for each interrupt
       in *ppIntContext */
    *ppIntContext = malloc(sizeof (DWORD));
    if (!*ppIntContext)
        return FALSE;
    /* In this sample the information is a DWORD used to
       count the incoming interrupts */
    pIntCount = (DWORD *) *ppIntContext;
    *pIntCount = 0; /* Reset the count to zero */
    return TRUE;
}
```

B.6.7. KP_IntDisable

Purpose

Called when `WD_IntDisable`() (see **WinDriver PCI Low-Level API Reference**) is called from the user mode for interrupts that were enabled in the Kernel PlugIn.
`WD_IntDisable`() is called automatically from `WDC_IntDisable`() [B.3.47] and `InterruptDisable`() (see **WinDriver PCI Low-Level API Reference**).

This function should free any memory that was allocated in `KP_IntEnable` [B.6.6].

Prototype

```
void __cdecl KP_IntDisable(PVOID pIntContext);
```

`KP_FUNC_INT_DISABLE` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input

Description

Name	Description
pIntContext	Interrupt context data that was set by `KP_IntEnable` [B.6.6]

Return Value

None

EXAMPLE

```
void __cdecl KP_IntDisable(PVOID pIntContext)
{
  /* You can free the interrupt specific memory
     allocated to pIntContext here */
  free(pIntContext);
}
```

B.6.8. KP_IntAtIrql

Purpose

High-priority legacy interrupt handler routine, which is run at high interrupt request level. This function is called upon the arrival of a legacy interrupt that has been enabled using a Kernel PlugIn driver – see the description of `WDC_IntEnable`() [B.3.46] or the low-level `InterruptEnable`() and `WD_IntEnable`() functions (see **WinDriver PCI Low-Level API Reference**).

Prototype

```
BOOL __cdecl KP_IntAtIrql(
    PVOID pIntContext,
    BOOL *pfIsMyInterrupt);
```

`KP_FUNC_INT_AT_IRQL` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
pfIsMyInterrupt	BOOL*	Output

Description

Name	Description
pIntContext	Pointer to interrupt context data that was set by `KP_IntEnable` [B.6.6] and will also be passed to `KP_IntAtDpc` [B.6.9] (if executed) and `KP_IntDisable` [B.6.7]
pfIsMyInterrupt	Set `*pfIsMyInterrupt` to `TRUE` if the interrupt belongs to this driver; otherwise set it to `FALSE` in order to enable the interrupt service routines of other drivers for the same interrupt to be called

Return Value

`TRUE` if deferred interrupt processing (DPC) is required; otherwise `FALSE`.

Remarks

- Code running at IRQL will only be interrupted by higher priority interrupts.
- Code running at high IRQL is limited in the following ways:
  - It may only access non-pageable memory.
  - It may only call the following functions (or wrapper functions that call these functions):
    - `WDC_xxx`() read/write address or configuration space functions.
    - `WDC_MultiTransfer`() [B.3.25], or the low-level `WD_Transfer`(), `WD_MultiTransfer`(), or `WD_DebugAdd`() functions (see the **WinDriver PCI Low-Level API Reference**).
    - Specific kernel OS functions (such as WDK functions) that can be called from high interrupt request level. Note that the use of such functions may break the code's portability to other operating systems.
  - It may **not** call `malloc`(), `free`(), or any `WDC_xxx` or `WD_xxx` API other than those listed above.
- The code performed at high interrupt request level should be minimal (e.g., only the code that acknowledges level-sensitive interrupts), since it is operating at a high priority. The rest of your code should be written in `KP_IntAtDpc` [B.6.9], which runs at the deferred DISPATCH level and is not subject to the above restrictions.

EXAMPLE

```
BOOL __cdecl KP_IntAtIrql(PVOID pIntContext,
    BOOL *pfIsMyInterrupt)
{
    DWORD *pdwIntCount = (DWORD*)pIntContext;

    /* Check your hardware here to see if the interrupt belongs to you.
       If it does, you must set *pfIsMyInterrupt to TRUE.
       Otherwise, set *pfIsMyInterrupt to FALSE. */
    *pfIsMyInterrupt = FALSE;

    /* In this example we will schedule a DPC once in every 5 interrupts */
    (*pdwIntCount) ++;
    if (*pdwIntCount==5)
    {
        *pdwIntCount = 0;
        return TRUE;
    }

    return FALSE;
}
```

B.6.9. KP_IntAtDpc

Purpose

Deferred processing legacy interrupt handler routine.
This function is called once the high-priority legacy interrupt handling is completed, provided that `KP_IntAtIrql` [B.6.8] returned `TRUE`.

Prototype

```
DWORD __cdecl KP_IntAtDpc(
    PVOID pIntContext,
    DWORD dwCount);
```

`KP_FUNC_INT_AT_DPC` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
dwCount	DWORD	Input

Description

Name	Description
pIntContext	Interrupt context data that was set by `KP_IntEnable` [B.6.6], passed to `KP_IntAtIrql` [B.6.8], and will be passed to `KP_IntDisable` [B.6.7]
dwCount	The number of times `KP_IntAtIrql` [B.6.8] returned `TRUE` since the last DPC call. If `dwCount` is 1, `KP_IntAtIrql` requested a DPC only once since the last DPC call. If the value is greater than 1, `KP_IntAtIrql` has already requested a DPC a few times, but the interval was too short, therefore `KP_IntAtDpc` was not called for each DPC request.

Return Value

Returns the number of times to notify user mode (i.e., return from `WD_IntWait`() – see the **WinDriver PCI Low-Level API Reference**).

Remarks

- Most of the interrupt handling should be implemented within this function, as opposed to the high-priority `KP_IntAtIrql` [B.6.8] interrupt handler.

- If `KP_IntAtDpc` returns with a value greater than zero, `WD_IntWait`() returns and the user-mode interrupt handler will be called in the amount of times set in the return value of `KP_IntAtDpc`. If you do not want the user-mode interrupt handler to execute, `KP_IntAtDpc` should return zero.

EXAMPLE

```
DWORD __cdecl KP_IntAtDpc(PVOID pIntContext, DWORD dwCount)
{
  /* Return WD_IntWait as many times as KP_IntAtIrql
     scheduled KP_IntAtDpc */
  return dwCount;
}
```

B.6.10. KP_IntAtIrqlMSI

Purpose

High-priority Message-Signaled Interrupts (MSI) / Extended Message-Signaled Interrupts (MSI-X) handler routine, which is run at high interrupt request level. This function is called upon the arrival of an MSI/MSI-X that has been enabled using a Kernel PlugIn – see the description of `WDC_IntEnable`() [B.3.46] or the low-level `InterruptEnable`() and `WD_IntEnable`() functions (see **WinDriver PCI Low-Level API Reference**).

Prototype

```
BOOL __cdecl KP_PCI_IntAtIrqlMSI(
    PVOID pIntContext,
    ULONG dwLastMessage,
    DWORD dwReserved);
```

`KP_FUNC_INT_AT_IRQL_MSI` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
dwLastMessage	DWORD	Input
dwReserved	DWORD	Input

Description

Name	Description
pIntContext	Pointer to interrupt context data that was set by `KP_IntEnable` [B.6.6] and will also be passed to `KP_IntAtDpcMSI` [B.6.11] (if executed) and `KP_IntDisable` [B.6.7]
dwLastMessage	The message data for the last received interrupt (applicable only on Windows Vista and higher)
dwReserved	Reserved for future use. Do not use this parameter.

Return Value

`TRUE` if deferred MSI/MSI-X processing (DPC) is required; otherwise `FALSE`.

Remarks

- Code running at IRQL will only be interrupted by higher priority interrupts.
- Code running at high IRQL is limited in the following ways:
  - It may only access non-pageable memory.
  - It may only call the following functions (or wrapper functions that call these functions):
    - `WDC_xxx`() read/write address or configuration space functions.
    - `WDC_MultiTransfer`() [B.3.25], or the low-level `WD_Transfer`(), `WD_MultiTransfer`(), or `WD_DebugAdd`() functions (see the **WinDriver PCI Low-Level API Reference**).
    - Specific kernel OS functions (such as WDK functions) that can be called from high interrupt request level. Note that the use of such functions may break the code's portability to other operating systems.
  - It may **not** call `malloc`(), `free`(), or any `WDC_xxx` or `WD_xxx` API other than those listed above.
- The code performed at high interrupt request level should be minimal, since it is operating at a high priority. The rest of your code should be written in `KP_IntAtDpcMSI` [B.6.11], which runs at the deferred DISPATCH level and is not subject to the above restrictions.

EXAMPLE

```
BOOL __cdecl KP_PCI_IntAtIrqlMSI(PVOID pIntContext,
    ULONG dwLastMessage, DWORD dwReserved)
{
    return TRUE;
}
```

B.6.11. KP_IntAtDpcMSI

Purpose

Deferred processing Message-Signaled Interrupts (MSI) / Extended Message-Signaled Interrupts (MSI-X) handler routine.
This function is called once the high-priority MSI/MSI-X handling is completed, provided that `KP_IntAtIrqlMSI` [B.6.10] returned `TRUE`.

Prototype

```
DWORD __cdecl KP_IntAtDpcMSI(
  PVOID pIntContext,
  DWORD dwCount,
  ULONG dwLastMessage,
  DWORD dwReserved);
```

`KP_FUNC_INT_AT_DPC_MSI` Kernel PlugIn callback function type.

Parameters

Name	Type	Input/Output
pIntContext	PVOID	Input/Output
dwCount	DWORD	Input
dwLastMessage	DWORD	Input
dwReserved	DWORD	Input

Description

Name	Description
pIntContext	Interrupt context data that was set by `KP_IntEnable` [B.6.6], passed to `KP_IntAtIrqlMSI` [B.6.10], and will be passed to `KP_IntDisable` [B.6.7]
dwCount	The number of times `KP_IntAtIrqlMSI` [B.6.10] returned `TRUE` since the last DPC call. If `dwCount` is 1, `KP_IntAtIrqlMSI` requested a DPC only once since the last DPC call. If the value is greater than 1, `KP_IntAtIrqlMSI` has already requested a DPC a few times, but the interval was too short, therefore `KP_IntAtDpcMSI` was not called for each DPC request.
dwLastMessage	The message data for the last received interrupt (applicable only on Windows Vista and higher)
dwReserved	Reserved for future use. Do not use this parameter.

Return Value

Returns the number of times to notify user mode (i.e., return from `WD_IntWait`() – see the **WinDriver PCI Low-Level API Reference**).

Remarks

- Most of the MSI/MSI-X handling should be implemented within this function, as opposed to the high-priority `KP_IntAtIrqlMSI` [B.6.10] interrupt handler.

- If `KP_IntAtDpcMSI` returns with a value greater than zero, `WD_IntWait`() returns and the user-mode interrupt handler will be called in the amount of times set in the return value of `KP_IntAtDpcMSI`. If you do not want the user-mode interrupt handler to execute, `KP_IntAtDpcMSI` should return zero.

EXAMPLE

```
DWORD __cdecl KP_IntAtDpcMSI(PVOID pIntContext, DWORD dwCount,
  ULONG dwLastMessage, DWORD dwReserved)
{
  /* Return WD_IntWait as many times as KP_IntAtIrqlMSI
     scheduled KP_IntAtDpcMSI */
  return dwCount;
}
```

B.6.12. COPY_TO_USER_OR_KERNEL, COPY_FROM_USER_OR_KERNEL

Purpose

Macros for copying data from the user mode to the Kernel PlugIn and vice versa.

Remarks

- The `COPY_TO_USER_OR_KERNEL` and `COPY_FROM_USER_OR_KERNEL` are macros used for copying data (when necessary) to/from user-mode memory addresses (respectively), when accessing such addresses from within the Kernel PlugIn. Copying the data ensures that the user-mode address can be used correctly, even if the context of the user-mode process changes in the midst of the I/O operation. This is particularly relevant for long operations, during which the context of the user-mode process may change. The use of macros to perform the copy provides a generic solution for all supported operating systems.

- Note that if you wish to access the user-mode data from within the Kernel PlugIn interrupt handler functions, you should first copy the data into some variable in the Kernel PlugIn before the execution of the kernel-mode interrupt handler routines.

- The `COPY_TO_USER_OR_KERNEL` and `COPY_FROM_USER_OR_KERNEL` macros are defined in the **WinDriver\include\kpstdlib.h** header file.

- For an example of using the `COPY_TO_USER_OR_KERNEL` macro, see the `KP_Call` [B.6.4] implementation (`KP_PCI_Call`()) in the sample **WinDriver/samples/pci_diag/kp_pci/kp_pci.c** Kernel PlugIn file.

- To safely share a data buffer between the user-mode and Kernel PlugIn routines (e.g., `KP_IntAtIrql` [B.6.8] and `KP_IntAtDpc` [B.6.9]), consider using the technique outlined in the technical document titled "How do I share a memory buffer between Kernel PlugIn and user-mode projects for DMA or other purposes?" found under the "Kernel PlugIn" technical documents section of the "Support" section.

B.6.13. Kernel PlugIn Synchronization APIs

This section describes the Kernel Plug-In synchronization APIs.
These APIs support the following synchronization mechanisms:

- Spinlocks [B.6.13.2–B.6.13.5], which are used to synchronize between threads on a single or multiple CPU system.

The Kernel PlugIn spinlock functions can be called from any context apart from high interrupt request level. Hence, they can be called from any Kernel PlugIn function **except** for `KP_IntAtIrql` [B.6.8] and `KP_IntAtIrqlMSI` [B.6.10].

Note that the spinlock functions **can** be called from the deferred processing interrupt handler functions – `KP_IntAtDpc` [B.6.9] and `KP_IntAtDpcMSI` [B.6.11].

- Interlocked operations [B.6.13.6–B.6.13.7], which are used for synchronizing access to a variable that is shared by multiple threads by performing complex operations on the variable in an atomic manner.

The Kernel PlugIn interlocked functions can be called from any context in the Kernel PlugIn, including from high interrupt request level. Hence, they can be called from any Kernel PlugIn function, **including** the Kernel PlugIn interrupt handler functions.

B.6.13.1. Kernel PlugIn Synchronization Types

The Kernel PlugIn synchronization APIs use the following types:

- **`KP_SPINLOCK`** – A Kernel PlugIn spinlock object structure:

```
typedef struct _KP_SPINLOCK KP_SPINLOCK;
```

`_KP_SPINLOCK` is an internal WinDriver spinlock object structure, opaque to the user.

- **`KP_INTERLOCKED`** – a Kernel PlugIn interlocked operations counter:

```
typedef volatile int KP_INTERLOCKED;
```

B.6.13.2. kp_spinlock_init()

Purpose

Initializes a new Kernel PlugIn spinlock object.

Prototype

```
KP_SPINLOCK * kp_spinlock_init(void);
```

Return Value

If successful, returns a pointer to the new Kernel PlugIn spinlock object [B.6.13.1], otherwise returns `NULL`.

B.6.13.3. kp_spinlock_wait()

Purpose

Waits on a Kernel PlugIn spinlock object.

Prototype

```
void kp_spinlock_wait(KP_SPINLOCK *spinlock);
```

Parameters

Name	Type	Input/Output
spinlock	KP_SPINLOCK*	Input

Description

Name	Description
spinlock	Pointer to the Kernel PlugIn spinlock object [B.6.13.1] on which to wait

Return Value

None

B.6.13.4. kp_spinlock_release()

Purpose

Releases a Kernel PlugIn spinlock object.

Prototype

```
void kp_spinlock_release(KP_SPINLOCK *spinlock);
```

Parameters

Name	Type	Input/Output
spinlock	KP_SPINLOCK*	Input

Description

Name	Description
spinlock	Pointer to the Kernel PlugIn spinlock object [B.6.13.1] to release

Return Value

None

B.6.13.5. kp_spinlock_uninit()

Purpose

Uninitializes a Kernel PlugIn spinlock object.

Prototype

```
void kp_spinlock_uninit(KP_SPINLOCK *spinlock);
```

Parameters

Name	Type	Input/Output
spinlock	KP_SPINLOCK*	Input

Description

Name	Description
spinlock	Pointer to the Kernel PlugIn spinlock object [B.6.13.1] to uninitialize

Return Value

None

B.6.13.6. kp_interlocked_init()

Purpose

Initializes a Kernel PlugIn interlocked counter.

Prototype

```
void kp_interlocked_init(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to initialize

© Jungo Ltd. 2005–2011

Return Value

None

B.6.13.7. kp_interlocked_uninit()

Purpose

Uninitializes a Kernel PlugIn interlocked counter.

Prototype

```
void kp_interlocked_uninit(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to uninitialize

Return Value

None

B.6.13.8. kp_interlocked_increment()

Purpose

Increments the value of a Kernel PlugIn interlocked counter by one.

Prototype

```
int kp_interlocked_increment(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to increment

Return Value

Returns the new value of the interlocked counter (`target`).

B.6.13.9. kp_interlocked_decrement()

Purpose

Decrements the value of a Kernel PlugIn interlocked counter by one.

Prototype

```
int kp_interlocked_decrement(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to decrement

Return Value

Returns the new value of the interlocked counter (`target`).

B.6.13.10. kp_interlocked_add()

Purpose

Adds a specified value to the current value of a Kernel PlugIn interlocked counter.

Prototype

```
int kp_interlocked_add(
    KP_INTERLOCKED *target,
    int val);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output
val	val	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to which to add
val	The value to add to the interlocked counter (`target`)

Return Value

Returns the new value of the interlocked counter (`target`).

B.6.13.11. kp_interlocked_read()

Purpose

Reads to the value of a Kernel PlugIn interlocked counter.

Prototype

```
int kp_interlocked_read(KP_INTERLOCKED *target);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to read

Return Value

Returns the value of the interlocked counter (`target`).

B.6.13.12. kp_interlocked_set()

Purpose

Sets the value of a Kernel PlugIn interlocked counter to the specified value.

Prototype

```
void kp_interlocked_set(
    KP_INTERLOCKED *target,
    int val);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output
val	val	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to set
val	The value to set for the interlocked counter (`target`)

Return Value

None

B.6.13.13. kp_interlocked_exchange()

Purpose

Sets the value of a Kernel PlugIn interlocked counter to the specified value and returns the previous value of the counter.

Prototype

```
int kp_interlocked_exchange(
    KP_INTERLOCKED *target,
    int val);
```

Parameters

Name	Type	Input/Output
target	KP_INTERLOCKED*	Input/Output
val	val	Input

Description

Name	Description
target	Pointer to the Kernel PlugIn interlocked counter [B.6.13.1] to exchange
val	The new value to set for the interlocked counter (`target`)

Return Value

Returns the previous value of the interlocked counter (`target`).

B.7. Kernel PlugIn Structure Reference

This section contains detailed information about the different Kernel PlugIn related structures. **`WD_XXX`** structures are used in user-mode functions and **`KP_XXX`** structures are used in kernel-mode functions.

The Kernel PlugIn synchronization types are documented in Section B.6.13.1.

B.7.1. WD_KERNEL_PLUGIN

Defines a Kernel PlugIn open command.

This structure is used by the low-level `WD_KernelPlugInOpen`() and `WD_KernelPlugInClose`() functions – see the **WinDriver PCI Low-Level API Reference**.

Field	Type	Description
hKernelPlugIn	DWORD	Handle to a Kernel PlugIn
pcDriverName	PCHAR	Name of Kernel PlugIn driver. Should be no longer than 12 characters. Should not include the VXD or SYS extension.
pcDriverPath	PCHAR	This field should be set to NULL. WinDriver will search for the driver in the operating system's drivers/modules directory.

Field	Type	Description
pOpenData	PVOID	Data to pass to the KP_Open [B.6.2] callback in the Kernel PlugIn.

B.7.2. WD_INTERRUPT

Interrupt information structure.

This structure is used by the low-level InterruptEnable(), InterruptDisable(), WD_IntEnable(), WD_IntDisable(), WD_IntWait() and WD_IntCount() functions. WDC_IntEnable() [B.3.46] calls InterruptEnable(), which in turn calls WD_IntEnable(), WD_IntWait() and WD_IntCount(). WDC_IntDisable() [B.3.47] calls InterruptDisable(), which calls WD_IntDisable().

Field	Type	Description
kpCall	WD_KERNEL_ PLUGIN_CALL	Kernel PlugIn message information structure [B.7.3]. This structure contains the handle to the Kernel PlugIn and additional information that should be passed to the kernel-mode interrupt handler. If the Kernel PlugIn handle is zero, the interrupt is installed without a Kernel PlugIn interrupt handler. If a valid Kernel PlugIn handle is set, this structure will passed as a parameter to the KP_IntEnable [B.6.6] Kernel PlugIn callback function.

For information about the other members of WD_INTERRUPT, see the description of InterruptEnable() in the **WinDriver PCI Low-Level API Reference**.

B.7.3. WD_KERNEL_PLUGIN_CALL

Kernel PlugIn message information structure. This structure contains information that will be passed between a user-mode process and the Kernel PlugIn. The structure is used when passing messages to the Kernel PlugIn or when installing a Kernel PlugIn interrupt.

This structure is passed as a parameter to the Kernel PlugIn KP_Call [B.6.4] and KP_IntEnable [B.6.6] callback functions and is used by the low-level WD_KernelPlugInCall(), InterruptEnable() and WD_IntEnable() functions. WD_KernelPlugInCall() is called from the high-level WDC_CallKerPlug() function [B.3.18]. InterruptEnable() (which calls WD_IntEnable()) is called from the high-level WDC_IntEnable() function [B.3.46].

Field	Type	Description
hKernelPlugIn	DWORD	Handle to a Kernel PlugIn, returned by `WD_KernelPlugInOpen()` (see the **WinDriver PCI Low-Level API Reference**) – which is called from `WDC_KernelPlugInOpen()` [B.3.17], and from the `WDC_xxxDeviceOpen()` functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) when called with the name of a Kernel PlugIn driver [12.4]
dwMessage	DWORD	Message ID to pass to the Kernel PlugIn
pData	PVOID	Pointer to data to pass to the Kernel PlugIn
dwResult	DWORD	Value set by the Kernel PlugIn, to return back to user mode

B.7.4. KP_INIT

This structure is used by the Kernel PlugIn `KP_Init` function [B.6.1]. Its primary use is to notify WinDriver of the given driver's name and of which kernel-mode function to call when `WD_KernelPlugInOpen()` (see **WinDriver PCI Low-Level API Reference**) is called from the user mode.

`WD_KernelPlugInOpen()` is called from the high-level `WDC_KernelPlugInOpen()` [B.3.17] function.
It is also called from the `WDC_xxxDeviceOpen()` functions (PCI [B.3.10] / PCMCIA [B.3.11] / ISA [B.3.12]) when these functions are called with a valid Kernel PlugIn driver (set in the `pcKPDriverName` parameter). However, to ensure the correct execution of your code in all scenarios – including execution of a 32-bit application with a 64-bit Kernel PlugIn driver – do not use the device-open functions to open a handle to the Kernel PlugIn driver.

Field	Type	Description
dwVerWD	DWORD	The version of the WinDriver Kernel PlugIn library.
cDriverName	CHAR[12]	The device driver name, up to 12 characters.
funcOpen	KP_FUNC_OPEN	Standard `KP_Open` callback function [B.6.2], which will be called when a user-mode

Field	Type	Description
		application opens a handle to a Kernel PlugIn driver [12.4], except when opening a handle to a 64-bit driver from a 32-bit application (in which case **`funcOpen_32_64`** will be used).
funcOpen_32_64	KP_FUNC_OPEN	`KP_Open` callback function [B.6.2] that will be called when a 32-bit application opens a handle to a 64-bit Kernel PlugIn driver [12.4], except for a 32-bit application request to open a handle to a 64-bit driver (when **`funcOpen_32_64`** will be used) [B.6.2].

B.7.5. KP_OPEN_CALL

This is the structure through which the Kernel PlugIn defines the names of its callback functions (other than `KP_Open`). It is used from the `KP_Open` [B.6.2] Kernel PlugIn function, which sets the callbacks in the structure.

A Kernel PlugIn may implement the following callback functions (other than `KP_Open` [B.6.2]):

- **funcClose** – Called when the user-mode process is done with this instance of the driver.

- **funcCall** – Called when the user mode process calls `WDC_CallKerPlug`() [B.3.18], or the low-level `WD_KernelPlugInCall`() function (see the **WinDriver PCI Low-Level API Reference**), which is called from `WDC_CallKerPlug`().
  This is a general-purpose function. You can use it to implement any functionality that should run in kernel mode (except the interrupt handler, which is a special case). The `funcCall` callback determines which function to execute according to the message passed to it from the user mode.

- **funcIntEnable** – Called when the user-mode process calls `WD_IntEnable`() with a Kernel PlugIn handle. `WD_IntEnable`() is called from `InterruptEnable`() (see **WinDriver PCI Low-Level API Reference**), which is called from the high-level `WDC_IntEnable`() function [B.3.46]. When calling `WDC_IntEnable`() with `fUseKP = TRUE`, the function calls `InterruptEnable`() with a Kernel PlugIn handle.
  This callback function should perform any initialization required when enabling an interrupt.

- **funcIntDisable** – Interrupt cleanup function, which is called when the user-mode process calls `WD_IntDisable`() – called from `InterruptDisable`() (see **WinDriver PCI Low-Level API Reference**), which is called from `WDC_IntDisable`() [B.3.47] – after having enabled interrupts using a Kernel PlugIn driver.

- **funcIntAtIrql** – High-priority kernel-mode legacy interrupt handler. This callback function is called at high interrupt request level when WinDriver processes a legacy interrupt that is assigned to this Kernel PlugIn. If this function returns a value greater than zero, the `funcIntAtDpc`() callback is called as a Deferred Procedure Call (DPC).

- **funcIntAtDpc** – Most of your legacy interrupt handler code should be written in this callback. It is called as a Deferred Procedure Call (DPC) if `funcIntAtIrql`() returned a value greater than zero.

- **funcIntAtIrqlMSI** – High-priority kernel-mode PCI Message-Signaled Interrupts (MSI) and Extended Message-Signaled Interrupts (MSI-X) handler. This callback function is called at high interrupt request level when WinDriver processes an MSI/MSI-X that is assigned to this Kernel PlugIn. If this function returns a value greater than zero, the `funcIntAtDpcMSI`() callback is called as a Deferred Procedure Call (DPC).
  Note: MSI/MSI-X is supported on Linux, Mac OS X, and Windows Vista and higher.

- **funcIntAtDpcMSI** – Most of your PCI MSI/MSI-X handler code should be written in this callback. It is called as a Deferred Procedure Call (DPC) if `funcIntAtIrqlMSI`() returned a value greater than zero.
  Note: MSI/MSI-X is supported on Linux, Mac OS X, and Windows Vista and higher.

- **funcEvent** – Called when a Plug-and-Play or power management event occurs, if the user-mode process first called `WDC_EventRegister`() [B.3.49] with `fUseKP = TRUE` (or if the low-level `EventRegister`() function was called with a Kernel PlugIn handle – see **WinDriver PCI Low-Level API Reference**). This callback function should implement the desired kernel handling for Plug-and-Play and power management events.

Field	Type	Description
funcClose	KP_FUNC_CLOSE	Name of your `KP_Close` [B.6.3] function in the kernel.
funcCall	KP_FUNC_CALL	Name of your `KP_Call` [B.6.4] function in the kernel.
funcIntEnable	KP_FUNC_INT_ENABLE	Name of your `KP_IntEnable` [B.6.6] function in the kernel.
funcIntDisable	KP_FUNC_INT_DISABLE	Name of your `KP_IntDisable` [B.6.7] function in the kernel.
funcIntAtIrql	KP_FUNC_INT_AT_IRQL	Name of your `KP_IntAtIrql` [B.6.8] function in the kernel.
funcIntAtDpc	KP_FUNC_INT_AT_DPC	Name of your `KP_IntAtDpc` [B.6.9] function in the kernel.

Field	Type	Description
funcIntAtIrqlMSI	KP_FUNC_INT_AT_IRQL_MSI	Name of your `KP_IntAtIrqlMSI` [B.6.10] function in the kernel. Note: MSI/MSI-X is supported on Linux, Mac OS X, and Windows Vista and higher.
funcIntAtDpcMSI	KP_FUNC_INT_AT_DPC_MSI	Name of your `KP_IntAtDpcMSI` [B.6.11] function in the kernel. Note: MSI/MSI-X is supported on Linux, Mac OS X, and Windows Vista and higher.
funcEvent	KP_FUNC_EVENT	Name of your `KP_Event` [B.6.5] function in the kernel.

B.8. User-Mode Utility Functions

This section describes a number of user-mode utility functions you will find useful for implementing various tasks. These utility functions are multi-platform, implemented on all operating systems supported by WinDriver.

B.8.1. Stat2Str

Purpose

Retrieves the status string that corresponds to a status code.

Prototype

```
const char *Stat2Str(DWORD dwStatus);
```

Parameters

Name	Type	Input/Output
dwStatus	DWORD	Input

Description

Name	Description
• dwStatus	A numeric status code

Return Value

Returns the verbal status description (string) that corresponds to the specified numeric status code.

Remarks

See Section B.9 for a complete list of status codes and strings.

B.8.2. get_os_type

Purpose

Retrieves the type of the operating system.

Prototype

```
OS_TYPE get_os_type(void);
```

Return Value

Returns the type of the operating system.
If the operating system type is not detected, returns `OS_CAN_NOT_DETECT`.

B.8.3. ThreadStart

Purpose

Creates a thread.

Prototype

```
DWORD ThreadStart(
    HANDLE *phThread,
    HANDLER_FUNC pFunc,
    void *pData);
```

Parameters

Name	Type	Input/Output
phThread	HANDLE*	Output
pFunc	typedef void (*HANDLER_FUNC)(void *pData);	Input
pData	VOID*	Input

Description

Name	Description
phThread	Returns the handle to the created thread
pFunc	Starting address of the code that the new thread is to execute. (The handler's prototype – `HANDLER_FUNC` – is defined in **utils.h**).
pData	Pointer to the data to be passed to the new thread

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.4. ThreadWait

Purpose

Waits for a thread to exit.

Prototype

```
void ThreadWait(HANDLE hThread);
```

Parameters

Name	Type	Input/Output
hThread	HANDLE	Input

Description

Name	Description
hThread	The handle to the thread whose completion is awaited

Return Value

None

B.8.5. OsEventCreate

Purpose

Creates an event object.

Prototype

```
DWORD OsEventCreate(HANDLE *phOsEvent);
```

Parameters

Name	Type	Input/Output
phOsEvent	HANDLE*	Output

Description

Name	Description
phOsEvent	The pointer to a variable that receives a handle to the newly created event object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.6. OsEventClose

Purpose

Closes a handle to an event object.

Prototype

```
void OsEventClose(HANDLE hOsEvent);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input

Description

Name	Description
hOsEvent	The handle to the event object to be closed

Return Value

None

B.8.7. OsEventWait

Purpose

Waits until a specified event object is in the signaled state or the time-out interval elapses.

Prototype

```
DWORD OsEventWait(
    HANDLE hOsEvent,
    DWORD dwSecTimeout);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input
dwSecTimeout	DWORD	Input

Description

Name	Description
hOsEvent	The handle to the event object
dwSecTimeout	Time-out interval of the event, in seconds. For an infinite wait, set the timeout to `INFINITE`.

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.8. OsEventSignal

Purpose

Sets the specified event object to the signaled state.

Prototype

```
DWORD OsEventSignal(HANDLE hOsEvent);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input

Description

Name	Description
hOsEvent	The handle to the event object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.9. OsEventReset

Purpose

Resets the specified event object to the non-signaled state.

Prototype

```
DWORD OsEventReset(HANDLE hOsEvent);
```

Parameters

Name	Type	Input/Output
hOsEvent	HANDLE	Input

Description

Name	Description
hOsEvent	The handle to the event object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.10. OsMutexCreate

Purpose

Creates a mutex object.

Prototype

```
DWORD OsMutexCreate(HANDLE *phOsMutex);
```

Parameters

Name	Type	Input/Output
phOsMutex	HANDLE*	Output

Description

Name	Description
phOsMutex	The pointer to a variable that receives a handle to the newly created mutex object

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.11. OsMutexClose

Purpose

Closes a handle to a mutex object.

Prototype

```
void OsMutexClose(HANDLE hOsMutex);
```

Parameters

Name	Type	Input/Output
hOsMutex	HANDLE	Input

Description

Name	Description
hOsMutex	The handle to the mutex object to be closed

Return Value

None

B.8.12. OsMutexLock

Purpose

Locks the specified mutex object.

Prototype

```
DWORD OsMutexLock(HANDLE hOsMutex);
```

Parameters

Name	Type	Input/Output
hOsMutex	HANDLE	Input

Description

Name	Description
hOsMutex	The handle to the mutex object to be locked

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.13. OsMutexUnlock

Purpose

Releases (unlocks) a locked mutex object.

Prototype

```
DWORD OsMutexUnlock(HANDLE hOsMutex);
```

Parameters

Name	Type	Input/Output
hOsMutex	HANDLE	Input

Description

Name	Description
hOsMutex	The handle to the mutex object to be unlocked

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.8.14. PrintDbgMessage

Purpose

Sends debug messages to the Debug Monitor.

Prototype

```
void PrintDbgMessage(
    DWORD dwLevel,
    DWORD dwSection,
    const char *format
    [, argument]...);
```

Parameters

Name	Type	Input/Output
dwLevel	DWORD	Input
dwSection	DWORD	Input
format	const char*	Input
argument		Input

Description

Name	Description
dwLevel	Assigns the level in the Debug Monitor, in which the data will be declared. If zero, `D_ERROR` will be declared. For more details please refer to `DEBUG_LEVEL` in **windrvr.h**.
dwSection	Assigns the section in the Debug Monitor, in which the data will be declared. If zero, `S_MISC` will be declared. For more details please refer to DEBUG_SECTION in **windrvr.h**.
format	Format-control string
argument	Optional arguments, limited to 256 bytes

Return Value

None

B.8.15. WD_LogStart

Purpose

Opens a log file.

Prototype

```
DWORD WD_LogStart(
    const char *sFileName,
    const char *sMode);
```

Parameters

Name	Type	Input/Output
sFileName	const char*	Input
sMode	const char*	Input

Description

Name	Description
sFileName	Name of log file to be opened
sMode	Type of access permitted. For example, NULL or **w** opens an empty file for writing, and if the given file exists, its contents are destroyed; **a** opens a file for writing at the end of the file (i.e., append).

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

Remarks

Once a log file is opened, all API calls are logged in this file.
You may add your own printouts to the log file by calling `WD_LogAdd`() [B.8.17].

B.8.16. WD_LogStop

Purpose

Closes a log file.

Prototype

```
VOID WD_LogStop(void);
```

Return Value

None

B.8.17. WD_LogAdd

Purpose

Adds user printouts into log file.

Prototype

```
VOID DLLCALLCONV WD_LogAdd(
    const char *sFormat
    [, argument ]...);
```

Parameters

Name	Type	Input/Output
sFormat	const char*	Input
argument		Input

Description

Name	Description
sFormat	Format-control string
argument	Optional format arguments

Return Value

Returns `WD_STATUS_SUCCESS` (0) on success, or an appropriate error code otherwise [B.9].

B.9. WinDriver Status Codes

B.9.1. Introduction

Most of the WinDriver functions return a status code, where zero (`WD_STATUS_SUCCESS`) means success and a non-zero value means failure.
The `Stat2Str`() functions can be used to retrieve the status description string for a given status code. The status codes and their descriptive strings are listed below.

B.9.2. Status Codes Returned by WinDriver

Status Code	Description
WD_STATUS_SUCCESS	Success
WD_STATUS_INVALID_WD_HANDLE	Invalid WinDriver handle
WD_WINDRIVER_STATUS_ERROR	Error
WD_INVALID_HANDLE	Invalid handle
WD_INVALID_PIPE_NUMBER	Invalid pipe number
WD_READ_WRITE_CONFLICT	Conflict between read and write operations
WD_ZERO_PACKET_SIZE	Packet size is zero
WD_INSUFFICIENT_RESOURCES	Insufficient resources
WD_UNKNOWN_PIPE_TYPE	Unknown pipe type
WD_SYSTEM_INTERNAL_ERROR	Internal system error
WD_DATA_MISMATCH	Data mismatch
WD_NO_LICENSE	No valid license
WD_NOT_IMPLEMENTED	Function not implemented
WD_KERPLUG_FAILURE	Kernel PlugIn failure
WD_FAILED_ENABLING_INTERRUPT	Failed enabling interrupt
WD_INTERRUPT_NOT_ENABLED	Interrupt not enabled
WD_RESOURCE_OVERLAP	Resource overlap
WD_DEVICE_NOT_FOUND	Device not found
WD_WRONG_UNIQUE_ID	Wrong unique ID
WD_OPERATION_ALREADY_DONE	Operation already done
WD_SET_CONFIGURATION_FAILED	Set configuration operation failed
WD_CANT_OBTAIN_PDO	Cannot obtain PDO
WD_TIME_OUT_EXPIRED	Timeout expired
WD_IRP_CANCELED	IRP operation cancelled

© Jungo Ltd. 2005–2011

Status Code	Description
WD_FAILED_USER_MAPPING	Failed to map in user space
WD_FAILED_KERNEL_MAPPING	Failed to map in kernel space
WD_NO_RESOURCES_ON_DEVICE	No resources on the device
WD_NO_EVENTS	No events
WD_INVALID_PARAMETER	Invalid parameter
WD_INCORRECT_VERSION	Incorrect WinDriver version installed
WD_TRY_AGAIN	Try again
WD_INVALID_IOCTL	Received an invalid IOCTL
WD_OPERATION_FAILED	Operation failed
WD_INVALID_32BIT_APP	Received an invalid 32-bit IOCTL
WD_TOO_MANY_HANDLES	No room to add handle
WD_NO_DEVICE_OBJECT	Driver not installed

Appendix C
Troubleshooting and Support

Please refer to http://www.jungo.com/st/support/support_windriver.html for additional resources for developers, including:

- Technical documents
- FAQs
- Samples
- Quick start guides

Appendix D
Evaluation Version Limitations

D.1. Windows WinDriver Evaluation Limitations

- Each time WinDriver is activated, an *Unregistered* message appears.
- When using DriverWizard, a dialogue box with a message stating that an evaluation version is being run appears on every interaction with the hardware.
- DriverWizard [4]:
  - Each time DriverWizard is activated, an *Unregistered* message appears.
  - An evaluation message is displayed on every interaction with the hardware using DriverWizard.
- WinDriver will function for only 30 days after the original installation.

D.2. Windows CE WinDriver Evaluation Limitations

- Each time WinDriver is activated, an *Unregistered* message appears.
- The WinDriver CE Kernel (**windrvr6.dll**) will operate for no more than 60 minutes at a time.
- DriverWizard [4] (used on a host Windows 7 / Vista / Server 2008 / Server 2003 / XP PC):
  - Each time DriverWizard is activated, an *Unregistered* message appears.
  - An evaluation message is displayed on every interaction with the hardware using DriverWizard.

D.3. Mac OS X WinDriver Evaluation Limitations

- Each time WinDriver is activated, an *Unregistered* message appears.
- DriverWizard [4]:
  - Each time DriverWizard is activated, an *Unregistered* message appears.
  - An evaluation message is displayed on every interaction with the hardware using DriverWizard.
- WinDriver's kernel module will work for no more than 60 minutes at a time. To continue working, the WinDriver kernel module must be reloaded (unload and load the module) using the following commands:

The following commands must be executed with root privileges.

To unload:

```
sudo kextunload /System/Library/Extensions/WinDriver.kext
```

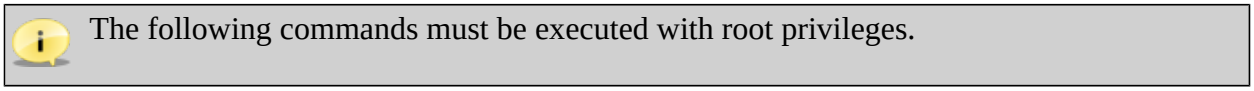
To load:

```
sudo <path to wdreg> WinDriver
```

wdreg is provided in the **WinDriver/redist** directory.

D.4. Linux WinDriver Evaluation Limitations

- Each time WinDriver is activated, an *Unregistered* message appears.
- DriverWizard [4]:
  - Each time DriverWizard is activated, an *Unregistered* message appears.
  - An evaluation message is displayed on every interaction with the hardware using DriverWizard.
- WinDriver's kernel module will work for no more than 60 minutes at a time. To continue working, the WinDriver kernel module must be reloaded (unload and load the module) using the following commands:



To unload:
```
/sbin/modprobe -r windrvr6
```

To load:
```
<path to wdreg> windrvr6
```

wdreg is provided in the **WinDriver/util** directory.

Appendix E
Purchasing WinDriver

Fill in the order form found in **Start | WinDriver | Order Form** on your Windows start menu, and send it to Jungo via email, fax or mail (see details below).

Your WinDriver package will be sent to you via courier or registered mail. The WinDriver license string will be emailed to you immediately.

Email		**Web Site**
Sales / Information:	sales@jungo.com	http://www.jungo.com
License Registration:	wd_license@jungo.com	

Phone		**Fax**	
Worldwide:	+972 74 721 2121	Worldwide:	+972 74 721 2122
USA (toll free):	+1 877 514 0537	USA (toll free):	+1 877 514 0538

Mailing Address

Jungo Ltd.
1 Hamachshev St.
P.O. Box 8493
Netanya 42504
Israel

Appendix F
Distributing Your Driver – Legal Issues

WinDriver is licensed per-seat. The WinDriver license allows one developer on a single computer to develop an unlimited number of device drivers, and to freely distribute the created drivers without royalties, as outlined in the license agreement in the **WinDriver/docs/license.pdf** file.

Appendix G
Additional Documentation

Updated Manuals

The most updated WinDriver user manuals can be found on Jungo's site at: http://www.jungo.com/st/support/support_windriver.html.

Version History

If you wish to view WinDriver version history, refer to the WinDriver Release Notes: http://www.jungo.com/st/wdver.html. The release notes include a list of the new features, enhancements and fixes that have been added in each WinDriver version.

Technical Documents

For additional information, refer to the WinDriver Technical Documents database: http://www.jungo.com/st/support/tech_docs_indexes/main_index.html.
This database includes detailed descriptions of WinDriver's features, utilities and APIs and their correct usage, troubleshooting of common problems, useful tips and answers to frequently asked questions.

© Jungo Ltd. 2005–2011